AMMAIA I: THE SURVEY

A Romano-Lusitanian Townscape Revealed

CRISTINA CORSI & FRANK VERMEULEN (eds.)

AMMAIA I: THE SURVEY

A Romano-Lusitanian Townscape Revealed

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PART I

CONTEXT

I.1 INTRODUCTION: SURVEYING A DESERTED ROMAN TOWN

C. Corsi, F. Vermeulen

This book epitomizes some of the most important results of the European funded project *"Radiography of the Past. Integrated non-destructive approaches to understand and valorise complex archaeological sites",* with the short title *Radio-Past*[1]. In order to achieve the target of developing integrated non-invasive approaches to investigate, interpret, visualize and valorize complex archaeological sites, the researchers of the project have selected several "test-sites" where innovation, experimentation and integration in different fields can be validated. This innovation in interdisciplinary methods ranges from field archaeology to geomorphology, from remote sensing to geophysical survey, from ICTs to Cultural Heritage management. The site of *Ammaia*, a deserted Roman town located in a remote area of the Portuguese Alto-Alentejo, not far from the Spanish border, has been chosen as the most important "open laboratory" of the project.

As will be explained in detail later, archaeological research started in *Ammaia* in the mid-1990's, and since 2001 Frank Vermeulen and Cristina Corsi have initiated collaboration here in the framework of an international project linking the Universities of Coimbra, Évora, Ghent and Cassino, in partnership with the *Fundação Cidade de Ammaia*, the institution currently in charge of the management of the archaeological park. Since 2007, both researchers have been appointed by the University of Évora as scientific directors of the site, a charge which will be concluded with the publication of this volume.

The Radio-Past project was launched in April 2009, and since then researchers belonging to the seven partner institutions[2] have carried out fieldwork and research in *Ammaia*, achieving quite spectacular results. This volume contains the final elaboration and interpretation of those results, presented in the light of the methodologies and strategies applied and contextualized in the framework of Iberian archaeology. The research results present a major contribution to the analysis of the phenomenon of Roman urbanism in the *Hispaniae*, and specifically in the province of *Lusitania*, established by Augustus in 27 BC in an area corresponding today to the central and southern part of Portugal and the almost entire Spanish region of Extremadura, where the capital *Augusta Emerita* was located (Fig. 1). In fact, even though important works of synthesis had already been published in the 1970s (Almagro Bash 1976), during the mid-1980s one of the best-known scholars in provincial Roman town planning, Guido Mansuelli, still stressed the difficulties of making a global analysis of Roman urbanism in Iberia, because of the poor availability of data (Mansuelli 1985). The slow rate of acquisition of archaeological data from the many ancient Iberian towns that developed into densely occupied Spanish and Portuguese cities brought M. Bendala Galán to stress again, in 1994, how those remarks were still valid (Bendala Galán 1994: 115), despite the fact that several attempts at approaching the subject were meaningful (e.g. Abascal 1989; *Les villes de Lusitanie romaine* 1990; Trillmich and Zanker 1990; Bendala Galán 1993). This lack of documentation was so evident that "for many years it has been possible to discuss the origin and development of towns in early Europe without any reference being made to Iberia, even though it occupies a key position between temperate Europe and North Africa and dominates the western edge of the Mediterranean" (Cunliffe and Keay 1995). Over the last fifteen years, however, there has been a veritable data explosion in which publications and syntheses have been barely able to keep pace with the speed of discovery. More so than on some of the new acquisitions from modern cities with ancient roots, like Barcelona, Tarragona, Lisbon or Évora, attention was rightfully focused on deserted towns like *Clunia*, *Belo Claudia*, *Valeria*, *Italica*, etc., where the contribution of new types of data acquisition and analysis (high resolution geophysics survey, remote sensing, GIS, etc.) revolutionized urbanism studies (e.g., Keay 1998; Osland 2006; Nogales Basarrate 2010*)*. This development is part of a wider trend all over the ancient world to study abandoned Roman towns using a wide array of modern survey methods which, when combined with more established approaches such as stratigraphic excavations and with the study of all legacy data concerning each particular town, can produce a much more complete vision of urbanism under Roman

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[1] See: www.radiopast.eu. The project (FP7 Marie Curie/People IAPP 2009, GA 230679) is part of an EC funded action meant to merge resources from public and private sectors.

[2] The Radio-Past consortium consists of four academic partners (the Portuguese University of Évora, coordinating institution, the Belgian Ghent University, the Slovenian University of Ljubljana and the British School at Rome, a Commonwealth organization, based in Rome) and three industrial beneficiaries (the Dutch Past2Present, the Austrian 7Reasons Media Agency and the German Eastern Atlas Meyer & Ullrich SMEs).

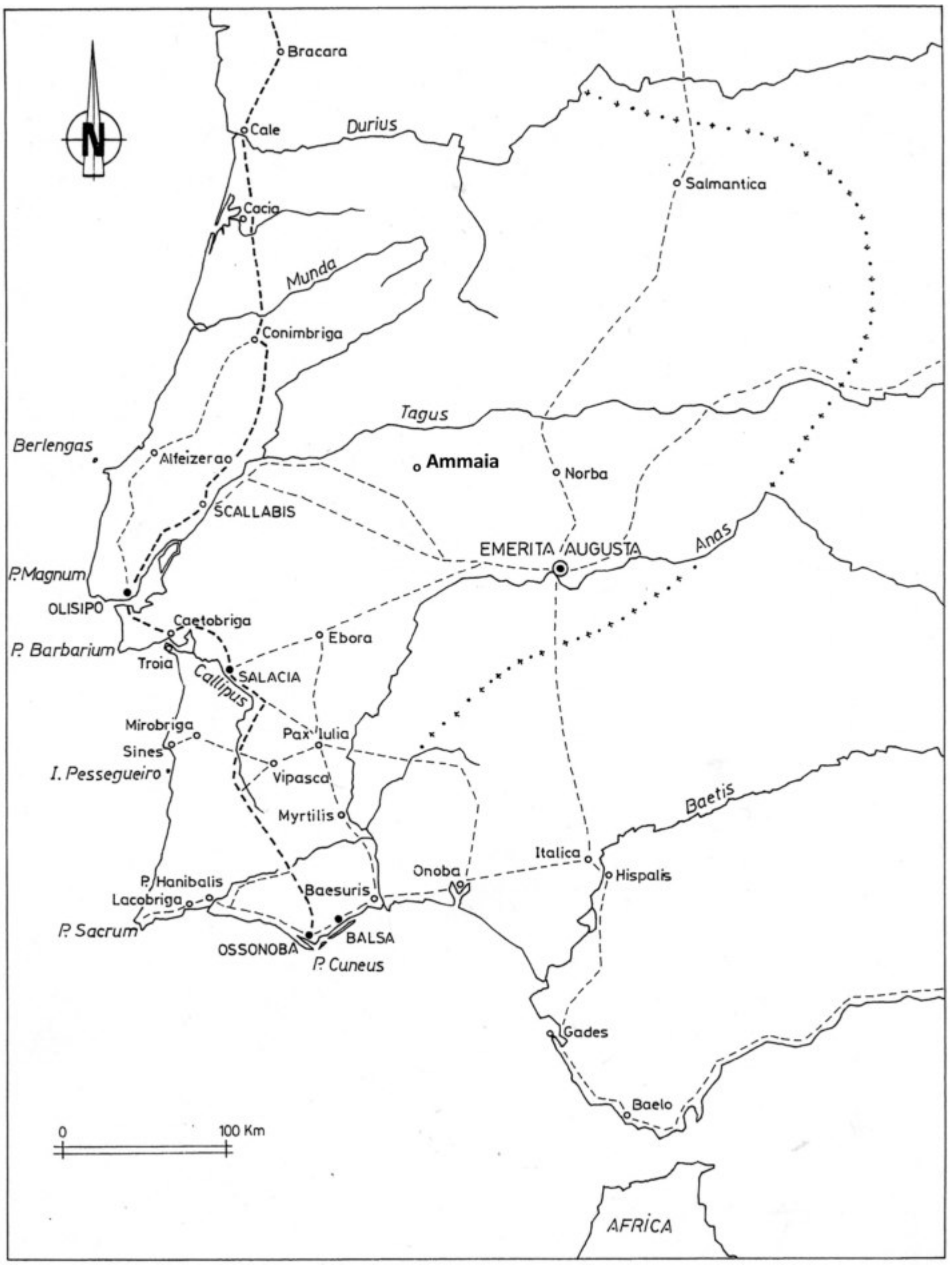

Fig. 1 Location of *Ammaia* with delineation of the main road network in *Lusitania* and the neighbouring Hispanic provinces (from Mantas 1998).

dominance (e.g., Christie and Augenti 2012; Johnson and Millett 2012; Vermeulen *et al.* 2012).

In this sense, the guidelines that inspired the researchers of the *Proyecto Italica* can be effectively targeted as a stimulating confrontation for the *Ammaia* open-lab: in this Roman town in Andalusia, the integrated programme of systematic surface survey and geophysics was meant to better understand the layout and chronology of the still buried parts of the town, and the integration with what was already known via traditional excavations aimed to correct, at the levels of both specialist and non-specialist visitors, the until then "partial" vision of the town in an attempt to better understand the scope of the Hadrianic project (Rodríguez Hidalgo and Keay 1995: 404-405).

In these past five years of intensive work in Portugal, we have been trying to promote the knowledge of *Ammaia*[3] but also to create a network of scientists and researchers who, although belonging to different disciplines and fields, are working on such themes. A first milestone is the publication of the proceedings of the International Colloquium "Changing Landscapes. The impact of Roman towns in the western Mediterranean", which was held in 2008 in *Ammaia* (Corsi and Vermeulen 2010). This book, with syntheses and selected case studies from the western Roman provinces and in particular from Iberia, demonstrated that a new generation of archaeol-

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[3] For a review of the most important publications on *Ammaia* see chapter I.2.

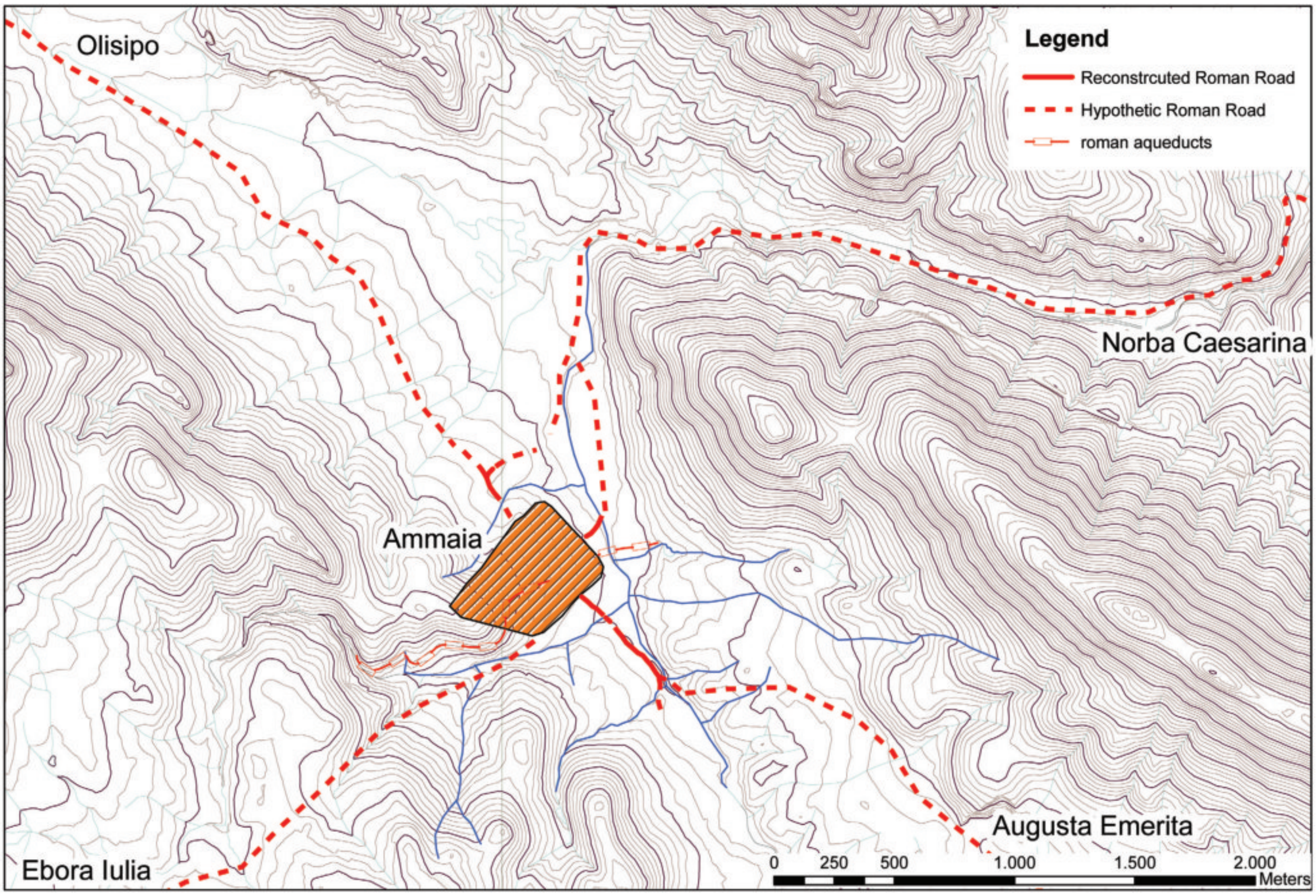

Fig. 2 *Ammaia* and its surroundings with indication of the main road-network (elaboration C. Corsi).

ogists has convincingly shown the crucial impact of Roman urbanism on the landscapes around these towns in the West. Using an array of new techniques, such as remote sensing and GIS-based spatial analysis, integrated with more traditional approaches, new ideas about the relationship of interdependency between town and territory have been developed. With the present publication, we aim to take the discussion one step further in the direction of an in-depth knowledge of the town centres and their immediate suburbs, based on such an integration of old and new style field archaeology.

Important in this debate is that the focus of Roman urbanism studies does not remain restricted to the provincial capitals and the larger, more monumentalized or better preserved cities in the West. It is essential also that mid-sized and smaller urban settlements are treated with respect: they indeed are the backbone of the urban world as the Romans developed it with the help of native populations. The great dynamism of such smaller towns, often well adapted to the regional situation and potential, is the secret of much urbanism in Roman times. This statement is particularly valid for large parts of the Iberian peninsula, where the intensive study of a whole range of such urban centres can help us to uncover the core of the Roman impact as well as to better understand regional perspectives.

The case study of *Ammaia* is a very suitable one in this respect. At this stage of research, we can state that *Ammaia* was a mid-size Roman town, strategically placed along the routes connecting the capital of the Lusitanian province *Augusta Emerita* (Mérida), and some of the most important towns of central *Lusitania*, like *Olisippo* (Lisbon), *Norba Caesarina* (Cáceres) and *Ebora Iulia* (Évora) (Fig. 2). *Ammaia* never reached the headlines in ancient literature: it is never cited in ancient sources, apart from an indication of its astronomical coordinates in Ptolemy (II, 5, 8; see also Guerra 1996: 17) and a brief mention in Pliny the Elder's encyclopaedia of the mountain range (the *Ammaeensia Iuga*), where a piece of rock crystal of outstanding dimension was found (*N.H.* XXXVII, 24; cf. XXXVII, 127)[4]. But the famous scholar fails to name *Ammaia* in the list of *civitates* of *Lusitania* (defined by Jorge de Alarção as towns with an "estatuto privilegiado": Alarção 1990b) contained in book IV, 117-118 of the *Naturalis Historia*. This absence from a crucial list can be explained in different ways: either the source used by the encyclopaedist is earlier than the foundation of the town itself (which, in this case, should pre-date the end of the first century BC) or it is merely a lapse in the text, as *Ammaia* would not be the only name forgotten by the author (Alarcão 1990b: 30).

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[4] For comments on this passage and possible links to Lusitanian Latin prosopography, see I.3.

The analysis of the archaeological record collected so far – including a revision of coin series and ceramics excavated since the 1990s – allows us to propose for *Ammaia* a foundation during the principate of Augustus, possibly in the last years of the first century BC or the very beginning of the new Era (Corsi, Johnson and Vermeulen 2012: 122). The foundation is clearly framed in a well-defined project, intended to create a settlement that could serve as a "central place" for the exploitation of the land and its natural resources (see chapter I.4) and as a junction along the road-network connecting inner and coastal *Lusitania*, which helped to design the layout of the town in detail.

At this stage we cannot establish what the original status of this settlement was. As we will see in detail later (see chapter I.3), one inscription of 44/45 AD qualifies *Ammaia* as a "*civitas*" (IRCP, 615: *civitas Ammaiensis*), and one of 166 AD defines it as a "*municipium*" (IRCP, 616: *municipes Ammaiensis*) and therefore we are sure that the town achieved first "*civitas*" and later municipal status. Thanks to the reference to specific public offices in other inscriptions (on which, see chapter I.3), we learn that some institutional change happened again during the Julio-Claudian dynasty, but the opinion adopted in this book is that it could have been the concession of the *Ius Latii* (Latin right). The elevation to the status of Latin *municipium* would therefore have happened in the span of time between the second half of the first and the first half of the second century AD[5].

Ammaia is traditionally included in the *Conventus Pacensis*, one of the three administrative compartments into which *Lusitania* is divided by Pliny, the other being the *Conventus Emeritensis* and the *Conventus Scallabitanus* (Tranoy 1990), but tentative proposals for the re-definitions of the borders and a re-allocation of *Ammaia* in the *Conventus Emeritensis* have been advanced (*Les villes de Lusitanie romaine* 1990: 325-326)[6].

The team authors of this book, early collaborators of the *Ammaia* project, like Vasco G. Mantas, formerly responsible for the *Ammaia*'s excavations, and Morgan De Dapper, Devi Taelman, Paul De Paepe and Jeroen Verhegge of Ghent University, or other researchers at the partner institutions of the Radio-Past project (all the others), will try to shed light on all these questions. We will present here the results achieved in *Ammaia* and its territory with non-invasive approaches, ranging from source collection and analysis of existing documentation (see I.2 and I.3), to topographical and geomorphological study (I.4, II.1 and II.2), remote-sensing (chapter II.3), geoarchaeological survey (chapter II.4), geophysical prospections (II.5) and surface artefact collection (II.6), with special attention paid to the digital reconstructions of the townscape based on the integrated interpretation of the exceptional results (chapters III.1 to III.3).

The next step in the production of research results from recent work in *Ammaia* will be the publication of the six excavated areas: the southern gate (*Porta Sul*), the baths (*Termas*), the forum temple and its surrounding portico, the housing sector under the eighteenth century farmhouse where the local museum is housed (Quinta do Deão) and the segments of walls and other structures found in the museum parking areas. This implies a careful re-interpretation of the excavations until 2005, which were generally not stratigraphical, and the presentation of the new stratigraphical investigations (baths: campaigns 2008, 2009, 2011; forum temple: campaigns 2010, 2011; forum portico: campaign 2010), carried out under the direction of Cristina Corsi and Frank Vermeulen. This publication series needs to be accompanied by the presentation of several categories of finds (fine wares, coarse wares, amphorae, glasses, coins), which at this stage are still under study by several doctoral and post-doctoral fellows of the Portuguese Fund for Research (FCT) attached to the University of Évora.

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[5] This opinion is also shared by Le Roux (1990: 44), stating that the concession of the individual citizenship (*viritim*) to Cornelius Macer suggests that the general "elevation" of the town happened at a later stage, possibly after the reign of Vespasian: see Alarção 1983: 27 and note 69. As noted by Richardson (1995: 348), we do not have to wonder about the fact that the monumental development of *Ammaia* in the course of the first century AD was not followed by a consequent upgrade of the political status. In spite of the fact that during Caesar and Augustus the number of cities had already increased noticeably, and surely many *coloniae* and *municipia* were founded, still "the material development… considerably outstripped the distribution of status". We can refer to the case of the well-known site of *Conimbriga*, which, in spite of possessing a forum, baths, and basilica, with temple and curia already in the Augustan age, still did not have a Roman status until Flavian times.

[6] Undoubtedly *Ammaia* is located in the vertex where the hypothetical limits of the *conventus Emeritensis, Scallabitanus* and *Pacensis* join. Possibly, the division between the *conventus Emeritenses* and *Scallabitanus* could be traced along the Serra da Lapa, east of the Serra da Estrela, following the Serra de Guardunha and ending at the Serra de S. Mamede (Albertini 1923: 102-103).

I.2 HISTORY OF ARCHAEOLOGICAL RESEARCH

F. Vermeulen

The site of the former Roman town of *Ammaia* is located in the municipality of Marvão, a part of the district of Portalegre in Alto Alentejo. The archaeological evidence of this now-abandoned town site lies mainly hidden in the hillside immediately south of the small 'street-village' of São Salvador de Aramenha, bordering on its south-eastern side the valley floor of the *Rio* Sever. Nowadays this terrain is mainly used for low key agricultural purposes, such as grassland with dispersed chestnuts, and some grain and olive cultivation. The upper parts of the hillside are taken up by light woodland and abandoned field terraces. Except for a handful of houses and farms, one of which was transformed into an archaeological on-site museum, the site is almost free of modern building construction. It is, however, crossed by the national road leading from Castelo de Vide to Portalegre. This attractive area and still peaceful site, lying within the national park of the Serra de São Mamede, have a long history of historical and archaeological investigations, be it that field research developed here along scientific lines only some 17 years ago.

A long phase of historical and often ill-documented archaeological approaches to ancient *Ammaia* preceded these field operations. Although the early studies have been sufficiently synthesized by others (Oliveira, Fernandes and Caeiro 1996: 15-22; Mantas 2000: 391-394; Pereira 2009: 23-36) and those of epigraphic character are discussed below (see chapter I.3), we will succinctly mention some of the most important ones. Already in the sixteenth century, the site attracted the attention of Portuguese and Spanish historians. In 1589 Frei Amador Arrais mentions the discovery of several Roman columns, marble funerary inscriptions, coins and gemstones, and notes the presence of numerous ancient towers and bridges over the Sever River (Arrais 1974). The many still visible ruins of the city were at that time still no major concern as no systematic registration or mapping of them was ever achieved. The site was being used on a regular basis as an interesting source for readily available building stones and in 1710 the then still standing southern gate of *Ammaia* (Fig. 3) was transferred to neighboring Castelo de Vide, where it stayed in use until 1891 (Coelho 1988; Stylow 2009; Mantas 2010).

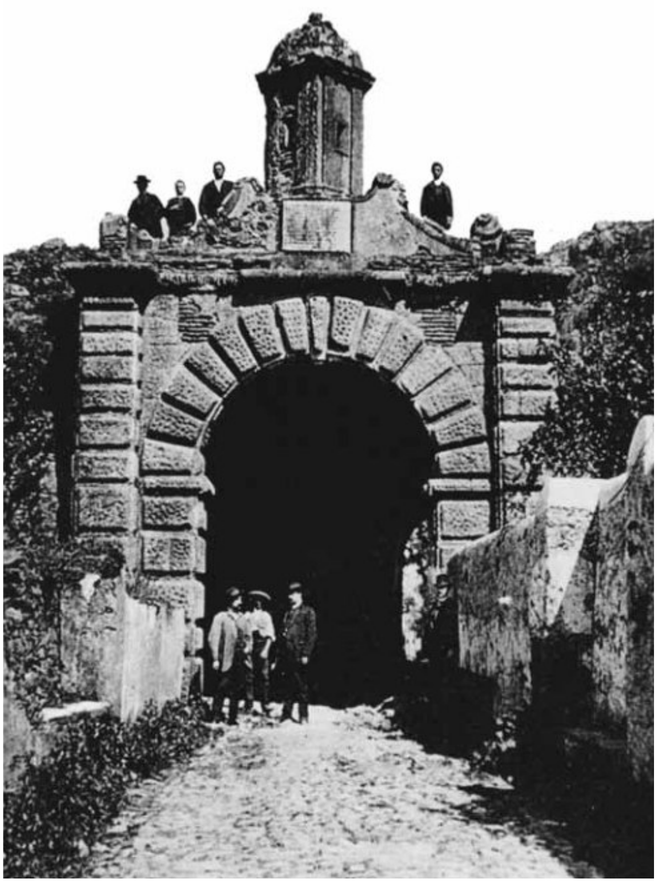

Fig. 3 In 1710 the then still standing southern gate of *Ammaia* was transferred to nearby Castelo de Vide, where it stayed in use until 1891. The image shows the gate in this secondary role, before its ultimate destruction.

More observations on finds are noted down from the mid-nineteenth century onwards. José de Viu (1852) describes the shipping of 20 large marble statues and several other artefacts to England, while many inscriptions, coins and other finds were now discovered and described. During the later nineteenth century and the early twentieth century, the first excavations revealed some of the town's *necropoleis* and many intact Roman burial gifts found their way into private and public collections (Pereira 2009). Sadly, topographical evidence about these burial sites is extremely limited, be it that most seem to be located in the area of the nearby village church. Until that period, archaeologists and historians believed that the ruins near São Salvador da Aramenha belonged to the Roman town of *Medobriga* and that the remains of *Ammaia* were located underneath the modern town of Portalegre, more than 10km to the south. It was not until 1935, when Leite de Vasconcelos published a

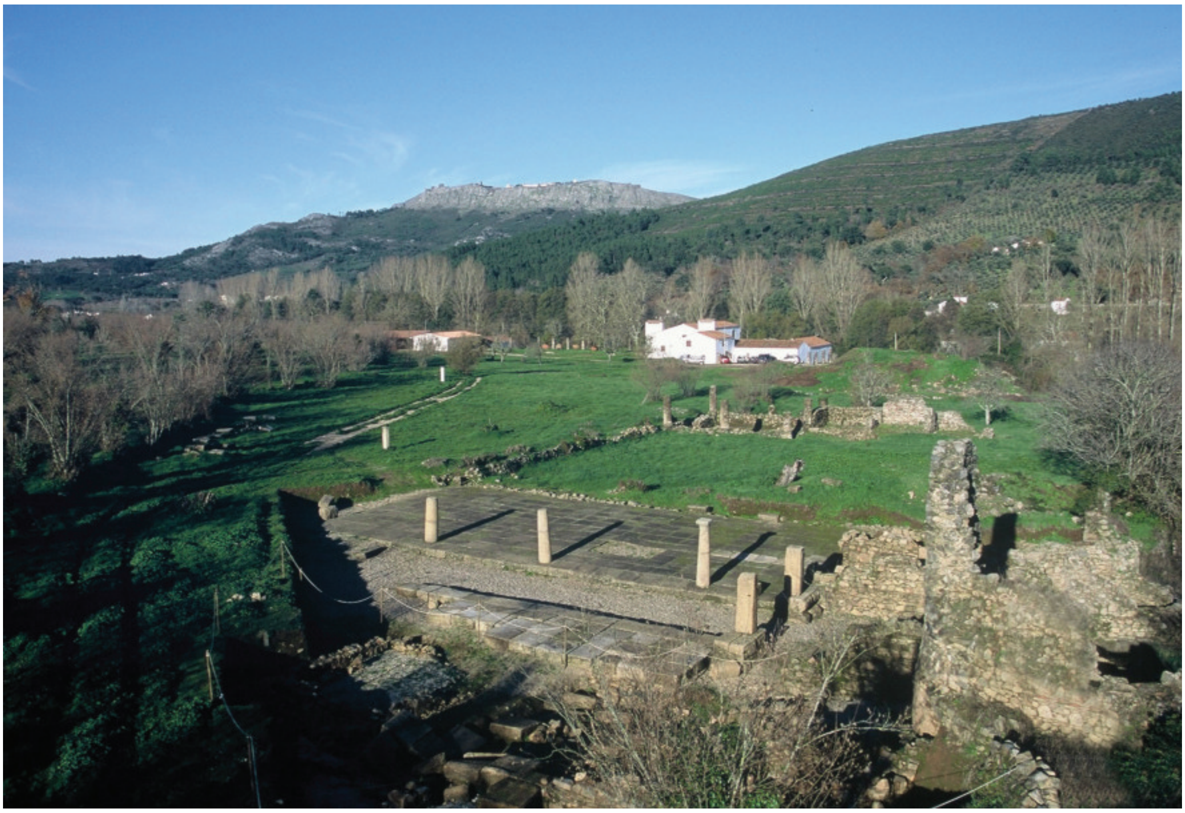

Fig. 4 View on the ruins and excavated area of Porta Sul and its annex square, with in the background the site museum, depot and laboratory. The hilltop on the horizon is dominated by the fortified medieval village of Marvão (photograph by João José Bica).

paper on the discovery of an honorific inscription dedicated to the Emperor Claudius (IRCP 615), that the Roman remains near São Salvador da Aramenha were identified as those of *Ammaia* (Vasconcelos 1935). Shortly after, the site was declared a National Monument (1949) and in 1994 the central area of the Roman town received the protected status of archaeological park. This event prepared the grounds for extending the historical and mainly epigraphic studies of recent decades (Jalhay 1947; IRCP 1984; Mantas 2000 and 2002) with documented excavations and more intense material studies.

Archaeological fieldwork and excavations in *Ammaia* have been taking place since 1994 (Mantas 2000; Oliveira, Pereira and Parreira 2007; Pereira 2009; Vermeulen and Taelman 2010). They were initiated by J. de Oliveira and from 1997 onwards, the operations have been organised by the *Fundação Cidade de Ammaia*, in close collaboration with the university of Évora. Teams from several foreign universities, such as from Ghent (Belgium), Louisville (USA), Cassino (Italy) and Dublin (Ireland) participated in the works since the early years, which were coordinated from 2000 onwards by V. Mantas of the University of Coimbra. Initial excavations have focused essentially on areas where visible ruins indicated the presence of subsurface Roman remains. These areas included parts of the city wall and the southern gate (*Porta Sul*) with associated monumental square and residential buildings (Fig. 4), parts of a public bathhouse (*Termas*), and parts of the forum complex where the *caementicium* core of the temple podium was still present above ground. In addition, a residential area underneath an abandoned farmhouse (Quinta do Deão) that now hosts the museum, and a small suburban area between the town and the River Sever were fully excavated. This first phase of intensive excavations was concluded in 2006. Part of the research results have been preliminarily published by several of the field archaeologists involved (Borges 2002; Pereira 2009), while other data remain unpublished and are partly described in annual fieldwork reports. The excavations delivered important information on a series of areas of the ancient city centre, procuring structural and chronological data on "windows" into the urban tissue. The operations were accompanied by some preliminary material studies, such as on gemstones, coins and fine-ware pottery, mainly aimed at reconstructing the town's general historical and chronological evolution.

Already in 2001, the need was felt to better understand the general topographical layout and landscape embedding of Roman *Ammaia*. Simultaneous with the ongoing excavations, a small team of researchers from the universities of Ghent and Cassino undertook in the course of the subsequent decade a geoarchaeological and topographic survey of this ancient city and its territory. A combination of fieldwalking, geomorphological analysis and study of aerial photographs has allowed, as a first phase, to reconstruct almost completely the circuit of the city walls, to identify several elements of the Roman street pattern, to suggest a plausible hypothesis for the location of the major roads connecting the town to its hinterland, to locate several possible buildings, extraction zones and infrastructures in the suburban area (e.g. aqueducts and quarries) and to suggest the identification of several funerary monuments along the roads entering the urban area (Vermeulen *et al.* 2005; Deprez, De Dapper and De Jaeger 2006; Deprez *et al.* 2009; Corsi and Vermeulen 2008 and 2009). Integrating survey evidence with stratigraphic data from the excavations it was also possible to consider questions about the taphonomy of the site and in particular its erosion history (Vermeulen, Corsi and de Dapper 2012). Field data were incorporated in a geographical information system (GIS), in which ancient and modern landscape data were integrated. In recent years a particular focus was laid on the geoarchaeological investigation of the complex interaction between the Roman provincial town and exploitation of mineral resources, such as gold, iron, granite and quartz, in its territory (Taelman *et al.* 2009; Deprez *et al.* 2009). Laboratory analyses, such as thin section petrography and geochemical analysis, were carried out to answer questions regarding the highly structured and heavily exploited rural landscape around Roman *Ammaia*. The main results from these geo-archaeological operations are presented below in this book (see mostly chapters I.4, II.1, II.3, II.4 and III.2).

In 2007 F. Vermeulen and C. Corsi took over the coordination of fieldwork on *Ammaia*, on behalf of the University of Évora. To test the geophysical potential of the archaeological site a large scale ground-penetrating radar survey (GPR) was achieved on the forum area in 2008, in collaboration with Ghent University (Verdonck, Taelman and Vermeulen 2008; see section II.5.c). The excellent results from these geophysical prospections incited the coordinators to select *Ammaia* as a field laboratory for the EC funded project Radio-Past, and to intensify non-invasive surveys in collaboration with all European partners (see I.1) and with extra support from FCT. Methodologically it was chosen to apply an integrated set of remote sensing techniques (low-altitude aerial photography, LiDAR, geomagnetometry, ground-penetrating radar survey and electrical resistance survey), topographic survey, geomorphological survey, systematic artefact survey, targeted ground-truthing, GIS-based analysis, photogrammetry, laser scanning and new 3D visualisation tools (Corsi, Johnson and Vermeulen 2012; Vermeulen, Corsi and De Dapper 2012; van Roode *et al.* 2012; Taelman and Vermeulen 2012). The spectacular fieldwork results obtained between 2009 and 2011 are presented and discussed hereunder. The surveys revealed and documented the almost full intra-mural town plan, many elements of the extra-mural activity (burial, production activity,…) during Roman and later times as well as the general ancient landscape setting. They limit the necessity for large-scale and costly excavation procedures in order to reveal this ancient town, but at the same time allow for the virtual visualization of the townscape and opening prospects for the sustainable touristic exploitation and cultural validation of a complex site.

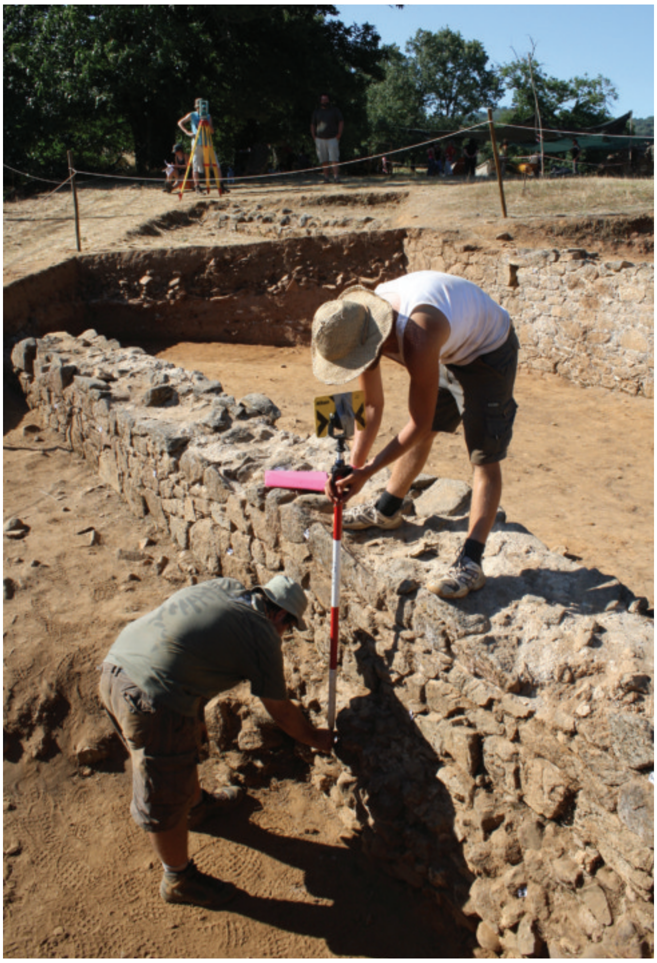

Fig. 5 Excavation activity in 2010 in the portico of the sanctuary on the forum showing the good and shallow preservation of Roman walls.

These intensive survey operations did not, however, fully erase the necessity of some excavation work on this site. Ground-truthing operations, in the shape of well-focused small-scale excavations, to evaluate the geophysical survey results were carried out on the forum complex (2010 and 2011) (Fig. 5) and the bathhouse just south of the forum (2008, 2009 and 2011). These digs mainly aimed at providing information on the structural, stratigraphic and chronological evolution of these areas of the town (Vermeulen, Corsi and De Dapper 2012). They were deemed essential in order to understand the nature of some of the geophysically revealed architectural and structural elements, to identify their material and character, to date them and propose some phases in the evolution of the forum and to understand the presumed Roman adaptations to the natural topography and local soil conditions. By way of such small scale intervention it would also be possible to complete and further expand the very insufficient data of earlier excavations conducted in these central areas of *Ammaia* between 1996 and 2002. The data assembled in the new excavations are at present being processed in association with a series of systematic material studies on find categories that provenance from this central area and all other excavated areas in *Ammaia*. These studies, on diagnostic groups such as fine ceramics, coarse pottery, amphorae, coins and glass will be fully published in the near future.

I.3 THE TOWN OF *AMMAIA* IN ANCIENT SOURCES

V. G. Mantas

Introduction

As with most Roman towns located within the territory of present day Portugal, there are only a few ancient literary sources available from which to derive knowledge about the history of the *municipium* of *Ammaia*. This unfortunate situation makes it necessary to resort, systematically, to archaeological and epigraphic testimony which, however, does not always prove to be sufficiently clear, even when the data provided are cross-referenced or compared with the evidence produced by archaeological excavations. The ruins of *Ammaia* were neglected until almost the end of the last century (Oliveira, Fernandes and Caeiro 1996: 15-22; Mantas 2000: 391-394), a fact which explains the loss of much valuable information, which was destroyed or dispersed without appropriate registration. A good example of this loss of important documentation is the epigraph of *duumvir* M. Iunius Gallus, which we came to know about through an English officer serving during the Peninsular War, but which was not followed up upon or referred to again and has remained missing ever since (Stylow 2009: 35-55).

Until 1935, the very identification of the *Ammaia* ruins was hindered by the lack of sources, a problem that was only solved when Leite de Vasconcelos recorded the honorific inscription with which the inhabitants of *Civitas Ammaiensis* engraved the annual vote in honour of the Emperor Claudius. This inscription was found in S. Salvador de Aramenha (Vasconcelos 1935: 5-9), thus confirming an alternative location for *Ammaia* to the one previously proposed by Hübner, that of present day Portalegre (Hübner 1869: 20-21). Indeed, as described in chapter I.2, the scholarly tradition had always identified the ruins of S. Salvador de Aramenha as being those of *Medobriga*.

Other inscriptions recorded and published in the nineteenth century, namely by the *Corpus Inscriptionum Latinarum*, also went missing but have been recovered in recent years, partly due to the restoration works carried out on the Quinta de Deão manor house for its later use as the small monographic museum of the *Ammaia* archaeological site. In some cases, it was possible to correct former readings, despite the fact that several epigraphs had been damaged through the reuse of their base, as happened with the marble plaque of the provincial Flamen G. Iulius Vegetus (*CIL* II 160 = IRCP 617). Although heavily worn on the right side of the area of inscription (Fig. 6), it still allows the name of his wife, Propinia Severa, to be clearly identified (Mantas 2004: 100-104). In spite of the prolonged dilapidation of the ruins – which caused artefacts such as the epigraph in honour of Lucius Verus to be spread significant distances from their places of origin, including pieces of considerable size, as happened with the famous Arch of Aramenha (see *supra* chapter I.2 and Mantas 2010b: 321-336) – new epigraphical remains are expected to emerge that are sure to contribute to our knowledge of the town. Even if most of the registered epigraphs are of more interest to the field of social rather than administrative history, some of them, although irritatingly ambiguous, are of great benefit to this latter field too, as we shall see.

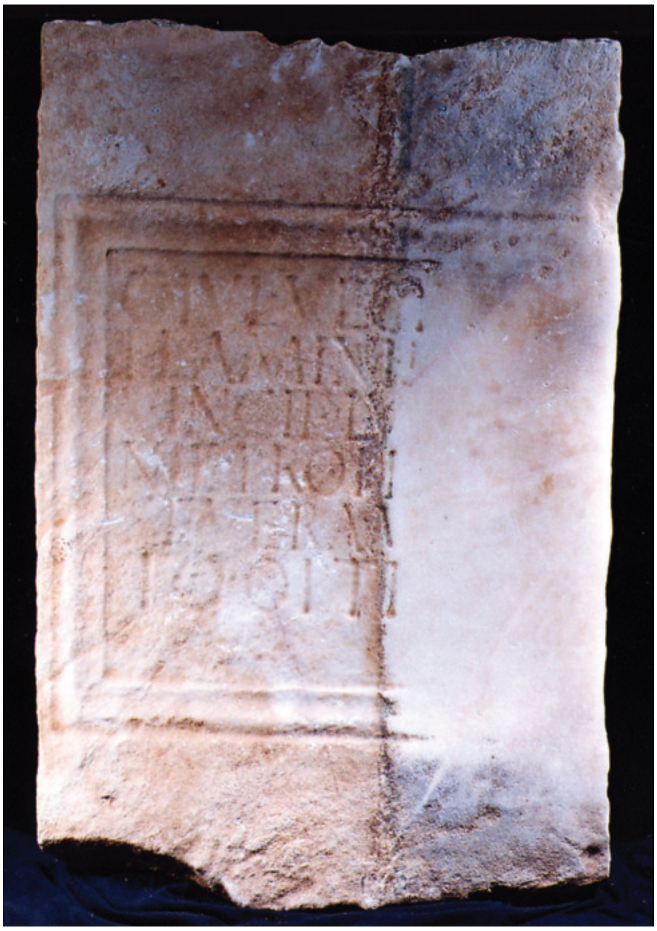

Fig. 6 Marble plaque dedicated to the *flamen* G. Iulius Vegetus (*Ammaia* Museum).

This preliminary introduction is justified for the reasons initially stated: our knowledge of *Ammaia*'s past is largely based on archaeological and epigraphical data due to the scarcity of other written sources, which amount to nothing more than clues from which little can be derived[1]. Some questions posed by the interpretation of these written sources can be answered or clarified by contrasting them with the archaeological evidence. In the same way, some literary references that do not allude directly to *Ammaia* should be taken into account, since they focus on aspects that are related to the town's history from a non-isolationist perspective.

Latin historiography on *Ammaia*

Let us start by reviewing some of these references in Latin historiography. The first refers to the relationship between *Herminius Mons*, usually identified as roughly corresponding to the Serra da Estrela, and the campaign against the Lusitanians conducted in 48 BC by Q. Cassius Longinus, which led to the destruction of *Medobriga*, a town that humanist historians have placed at S. Salvador de Aramenha through an obscure line of toponymic reasoning that associates Aramenha with *Herminius* through the intermediate name *Herminia*. The reference in *De Bello Alexandrino*, possibly written by Aulus Hirtius, is laconic: "Thus, by assembling the whole army at one place and by promising one hundred sesterces to the soldiers, he shortly after took the fortified town of *Medobriga* and *Herminius Mons*, where he was acclaimed Imperator*"* (Hirtius, *Bell. Alex*., 48, 2). From this, we can take the Serra de S. Mamede to be *Herminius Minor*, which immediately contradicts the absence of this orographic toponym in Pliny the Elder, who merely referred to the hilly region of *Ammaia* as *Ammaeensibus iugis* (Pliny, *N.H.*, XXXVI, 24).

This fanciful connotation of Aramenha with *Herminius Mons*, without any support in classical sources, was widely accepted by researchers (Guerra 1996: 7-33) and can still occasionally be found in less informed publications. The influence of scholarly authority is also reflected in local legends, even of relatively recent creation, as in that of the Castelo de Marvão (Marques 1997: 159-168). Here, in line with the usual pattern of these narratives, a villain by the name of Cassius Longinus confronts a maiden appropriately named Amaia. The source of the toponym Monte Hermínio, designating a property in the vicinity of the ruins of *Ammaia* and close to the confluence of two rivers, the Ribeira de Porto de Espada and the Sever, is probably the same, although the property appeared in the 1512 Manueline Charter of Marvão as Monte Arminho (Coelho 1988: 55-56, 99). In any case, there is nowadays no evidence that could possibly justify, or even allow for, the identification of the ruins of S. Salvador de Aramenha as being the *Medobriga* of ancient sources. Without wishing to interfere in ongoing language disputes, we do not exclude a relationship between Aramenha and Aramanha (*Ara Magna*), a toponym which can sometimes be found in areas where there was a heavy Roman presence, as for example on the outskirts of Santarém. The same could apply to S. Salvador de Aramenha, located at the northern corner of the urban ruins and eventually related to some large funerary monument of a type that we know to have existed in *Ammaia* (Mantas 2000: 408; Corsi and Vermeulen 2008: 167, 189-192). This hypothesis is reinforced by the fact that a necropolis was identified in the area in question.

Pliny the Elder's reference is laconic and indirect as it does not allude to the town but to the rock crystal existing in the elevated parts of the region and generally referred to as *Ammaeensibus iugis.*[2] Despite the difficulties in situating the mines that supplied this important economic resource, which in Antiquity was regarded as a kind of perennial ice and very much appreciated for the making of jewellery, their location was confirmed, centuries later, through an Islamic source, incidentally no less imprecise than the description by Pliny: *"Cornelius Bocchus et in Lusitania perquam mirandi ponderis in Ammaeensibus iugis, depressis ad libramentum aquae puteis*" (Pliny, *N.H.*, XXXVII, 127).

As a matter of fact, al-Himyari indicates the source of rock crystal as being some 40 miles north of Badajoz (Torres Balbás 1982: 770), which, although somewhat vague, still points to the region concerned, since the geodesic distance between Badajoz and S. Salvador de Aramenha is about 65km, not counting the Islamic villages of some importance that al-Himyari could have indicated as reference points in the intervening area (Sidarus 1991: 14-16). Given that al-Himyari also indicates a distance of 40 miles between Mértola and Beja, we can situate the rock crystal exploration in the Serra de S. Mamede area, without forgetting that the metrology of Islamic geographers does not always use the exact same measure for a mile. In any case, these are certainly the same deposits indicated by Pliny, an author we would like to return to, this time with regard to an unusual gemstone and, once again, related to a text by Cornelius Boccus, a writer and eminent figure among the Lusitanian notables of the Julio-Claudian era: "*Bocchus auctor est et in Hispania repertas quo in*

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[1] We soon intend to publish the *corpus* of Roman inscriptions of the Municipality of Marvão, on which we have been working for some years by gathering all the presently known monuments, as well as completing and reviewing the data published by José d'Encarnação in his important work (IRCP 1984: 667-694, 777, 849).

[2] For the identification of possible quarry areas, see chapter I.4 in this volume.

loco crystallum dixit ad libramentum puteis defossis erui, chrysolithon XII pondo a se visam" (Pliny, *N.H.*, XXXVII, 24).

The explicit statement that Bocchus actually saw the referred gemstone makes us question the origins of one of the more prominent figures of the early period of the urbanization of *Ammaia*, a certain Publius Cornelius Macer, who was granted Roman citizenship by Emperor Claudius and consequently registered with the Quirina tribe (IRCP 1984: 679-681; Encarnação 1986: 107; Mantas 2000: 410-411). This suggests strong patronage of Macer who we believe to have been a native elevated to the status of Roman citizen for reasons that naturally escape us, but which we can easily relate to a phase in the development of the town prior to it being granted Latin right – a subject we will return to later on (Fig. 7). We know today that several Cornelii Bocchi were active in the Julio-Claudian period, especially in *Salacia* (Alcácer do Sal) and Tróia, but also in other places where they left more or less obvious traces of their influence, such as *Olisipo* (Lisbon), *Scallabis* (Santarém), the Alentejo, near Arraiolos, and perhaps *Emerita* (Mérida) (Encarnação 2011: 189-201). Thus, it seems very likely that the promotion of Macer can be explained in light of the interests pursued by the Cornelii in the Alto Alentejo, which includes the writer referred to by Pliny. Given the fact that there are no known representatives of the *gens* Cornelia in the north-eastern Alentejo other than the one recorded in *Ammaia* (Encarnação 1987: 169), this hypothesis seems to be very plausible and worthy of further investigation.

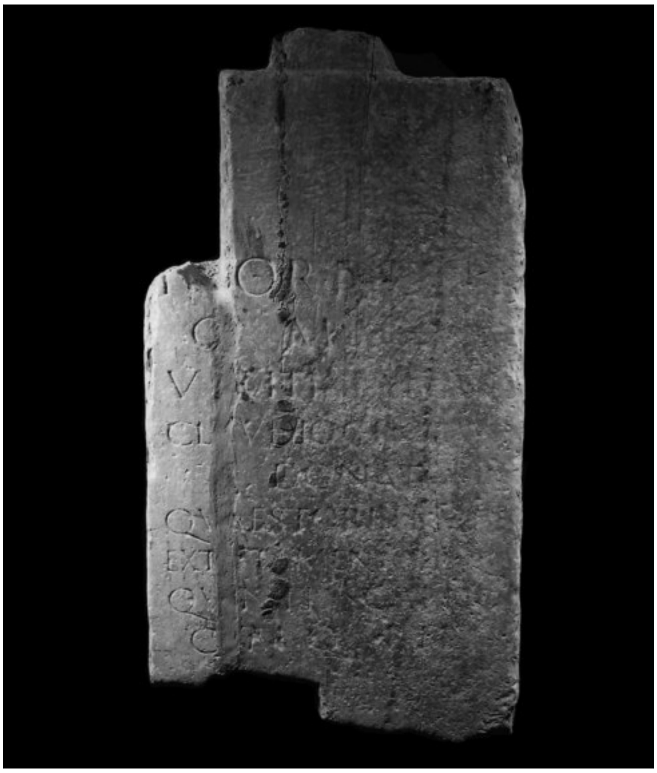

Fig. 7 Pedestal (?) of P. Cornelius Q. Macer (*Ammaia* Museum).

Another reference to the ancient city of *Ammaia* can be found in Claudius Ptolemy's *Geographia*, a work completed in the mid-second century in Alexandria (Ptolemy, *Geog.*, II, 5, 8). This author enumerated a long list of settlements and geographical features, located by means of a system of coordinates that at present is difficult – but not impossible – to use, and whose coordinates may have been partly derived from ancient road and port maps. Thus, the coordinates help to calculate the distances between different cartographical locations, providing interesting elements of comparison with the indications given by the *Antonini Itinerarium*. We consider that every minute of a Ptolemaic degree is equivalent to 1.05 Roman miles, a relation that can be used with reasonable confidence in the operations of triangulation that are needed to transform the differences between coordinates into linear values. With regard to *Ammaia* (Ἀμμαία), Ptolemy defined the following coordinates: 7° longitude, 39° 20' latitude. Now, these figures put *Ammaia* at a distance of 64 Roman miles from *Norba Caesarina* (Cáceres), equivalent to the 95km that separate them by road.

We believe that this coincidence proves the existence of a road going past Valência de Alcântara, which connected the two towns and continued in the direction of the River Tagus, despite the difficulties of its identification in the landscape. If we consider the distance to *Emerita Augusta* (Mérida), which in a straight line is about 102km, we encounter the equivalent of 96km, by default a negligible error, which is annulled if we consider the variant via Albuquerque. As for the town of *Olisipo*, the calculated distance seems to correspond to the length of the road which, via *Abelterium* (Alter do Chão), connected it with *Ammaia* (Fig. 8). Although much in the ancient sources needs to be treated with caution, we believe that *Geographia* can be used to situate *Ammaia*, even if the road maps that have come down to us through history do not corroborate the town's road connections (Roldán Hervás 1975: 212; gravures 3, 12). Finally, Ptolemy places the town in the territory inhabited by the Lusitanians, which in fact covers the whole of present day Alto Alentejo, a fact that cannot be explained by mere population transfer, as has been defended based on Strabo, and much less as a consequence of forced relocations ordered by Caesar and Augustus (Cassius Dio, XXXVII, 52, Floro, II, 33, 52). The obvious and widespread Lusitanian onomastics of the region does not allow for such an interpretation.

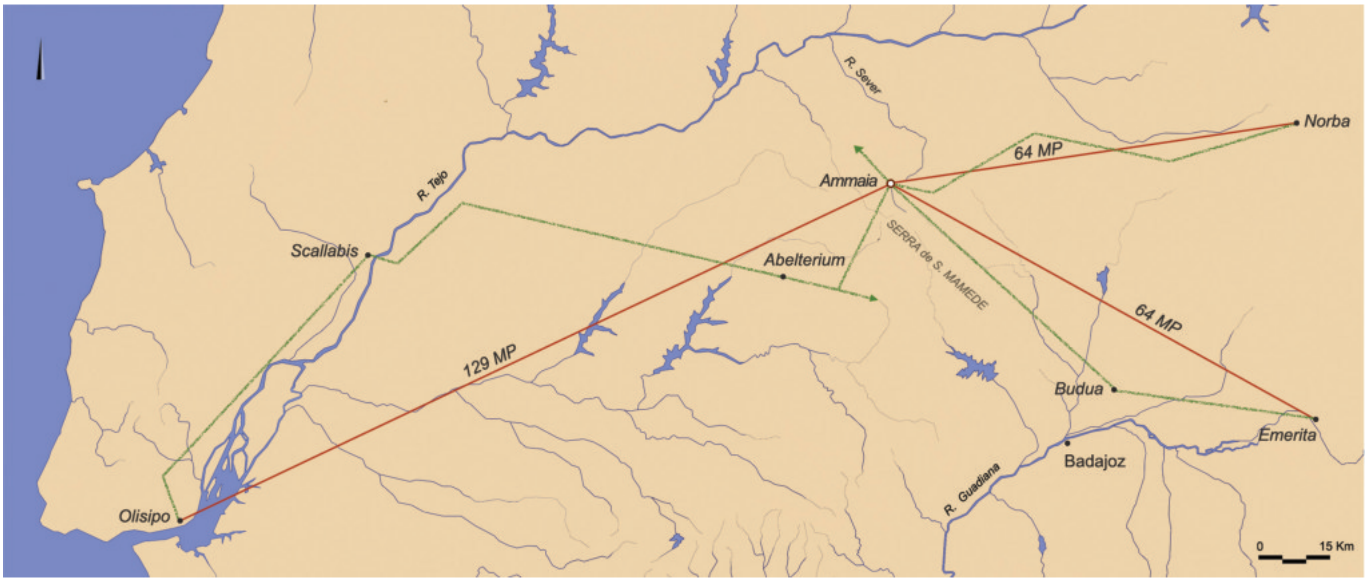

Fig. 8 Road network and Ptolemaic data. Approximate localizations of *Ammaia*, *Emerita*, *Norba* and *Olisipo*.

Epigraphic sources

Let us now focus on the epigraphic sources from either the region or the ruins of the ancient town. As is well known, these sources represent only a fraction, no more than 5% on average, of the total that may have existed in the past. We are therefore limited by quantity as much as we are subject to the arbitrariness of the findings, a fact that demands caution when attempting to write history based on these – undeniably irreplaceable – documents. Another question that arises, and which is not unique to *Lusitania* or this specific area, is the chronology of the inscriptions, which overwhelmingly fall into the period of the height of the Roman Empire. The epigraphic *corpus ammaiensis* comprises a reasonable number of inscriptions, preserved or lost, but in any case transcribed, a part of which is presently exhibited at the *Ammaia* Museum under very good conditions (Fig. 9). The respective bibliography is also rather extensive, though only a small portion is the result of recent epigraphic studies. These sources are particularly important when analysing the process of the town's legal and administrative development, as well as the composition of its population and its connections to the outside world.

Fig. 9 Detail of the epigraphy room at the *Ammaia* Museum.

We will start with the testimonies of the town's evolution and, above all, with its still much discussed status. Though the date of its elevation to *municipium* remains somewhat unclear, if we consider a possible gap between the concession of Latin right and the granting of municipal status (Galsterer 1988: 68-70; Le Roux 1995: 83-87), the question of the tribe is definitively resolved, leaving no reasonable doubt regarding its registration with the Quirina tribe, which, for many researchers, should be sufficient to consider *Ammaia* a Flavian municipality (Pintado 2004: 343-364). Unfortunately, the problem is not that simple. Everything indicates that the town was founded by Augustus in the context of a plan to reorganize *Lusitania* through the creation of *civitates* (Alarcão 1990c: 386-390). This programme, however, expanded over time, as proven by the chronology of the various *terminus Augustalis* found throughout the province (Bárcena 2002-2003: 107-125). We certainly do not follow the hypothesis, solely based on the reading of an inscription found in Albuquerque (*CIL* II 724), that *Ammaia* could have been one of the prefectures of *Emerita*, even if Albuquerque had belonged to the territory of *Ammaia* instead of that of the capital of *Lusitania*, which, for now, cannot be proven.

With regard to the essential question, the creation of the town and its development until the granting of municipal status, we now have five inscriptions that allow us to outline a general picture, but which fail to inform us on the precise dates of the change in status, except for the last one. The first of these inscriptions dates from the year 44/45, during the time of Claudius' principate, and alludes to *Ammaia* as a peregrine settlement governed by native magistrates, like so many others: *Tib. Claudio / Caesari. Aug. / Germanico. imp. III / pont. max. trib. pot. / IIII. cos. III. desig. IIII / Civitas Ammaiensis / ex voto. annuo / L. Calventio. Vetere. / Carmini. leg. / Tib. Claudi. Caesaris. Aug / Proculo. Pisiri. f / Omuncione. Cilai. f* (IRCP 615). Thus, we know that in 44 or 45 the town was still restricted to a peregrine status, though we are not able to say since when, and marginal in the hierarchy of Roman urban centres. We would like to recall that, a little earlier, a similar vote had been expressed by the inhabitants of *Aritium Vetus* (Alvega?). This vote was addressed to the Emperor Caligula in the year of 37, also on the initiative of two native magistrates (*CIL* II 172 = IRCP 647), something that does not occur in the inscription dated 16 BC from the town of the *Igaeditani* (Idanha-a-Velha), where four magistrates are named (Mantas 2006: 61-65).

Around 44 AD, however, something was going to change in *Ammaia*, as is strongly suggested by the second inscription of the above mentioned group of five (*CIL* II 159 = IRCP 618), which was also found in S. Salvador Aramenha: *P [C]ornelio / Q Macro / viritim a Divo Claudio civit[ate] / donato / quaestori II viro / ex testamento ip[sius] / Quintius. Ca[p]ito / cum Q f h [p].* This epigraph, possibly belonging to a monumental base, has a rather troubled history, causing repeated discussions among experts. Lost and truncated after its first registration (IRCP: 679-681; Encarnação 1986: 107; Stylow, Abascal and Cebrián 2009: 25, 28-29), debate has dragged on about its meaning, and even about the presence of the letter Q at the beginning of the second line of the epigraph. Once the missing fragment was recovered, the presence of the letter Q was confirmed, to which we cannot give any other interpretation than Q(*uirina*), which is corroborated by both the epigraphs of G. Sentius Capito and M. Iunius Gallus – also found at the Quinta do Deão (Mantas 2004: 92-97; Stylow 2009: 33-46) – and the inscriptions of Monforte (IRCP 578, 595a), where the tribe is always identified as being that of Quirina. Since no urban centres are known to have been promoted in the Iberian Peninsula by Nero, the status of *municipium* must have been granted in Claudian times – or, alternatively, the concession of Latin right, considering the positions held by Cornelius Macro. Either that or an earlier date must be assigned to the inscription in order to maintain the thesis of a Flavian municipality (Stylow 1997: 105-123; Pintado 2004: 343-364). The well known inscription of *Sabora* in *Baetica* (*CIL* II 1423) forces us to question this thesis, since it is hardly acceptable in many situations. In fact, we can only be certain that a change of status took place between 44/45 and 74 AD, which we believe to have been the concession of Latin right, whereas we consider the Julio-Claudian period the most plausible for this to have taken place. One wonders if the status of *municipium* had been granted at the same time.

A third inscription sheds some light on this issue, although rather diffuse, probably reflecting the granting of Latin right to *Ammaia: Genio Oppid[i] Constitut[i] / sacrum // C. Annius / Valens / a l d* (IRCP 604). Again we have a kind of birth certificate of the town, devoid of chronology other than the one inferred by study of the monument (Fig. 10). Contrary to other opinions, we believe that this is not the physical birth of the town, but its constitution as an urban centre integrated into the Roman judicial order through the concession of Latin right, most probably under the Principate of Claudius. With regard to the monument, the difficulties associated with its dating match the prudence shown by Encarnação, who preferred to focus on the meaning of the expression *Oppidi Constituti*, to which he attributed a legal sense, though again with caution. This is also our opinion, shared by Amilcar Guerra, who directly relates the votive stone to the concession of Latin right to *Ammaia* by the Emperor Claudius (Guerra 1996: 28-29). The opposite opinion, supported by arguments that do not differ significantly from those already presented, is maintained by Stylow, who suggests that the mentioned expression does not mean 'legally constituted', but rather 'built', though he accepts the dating of the monument to the Julio-Claudian period (Stylow 2009: 47-48).

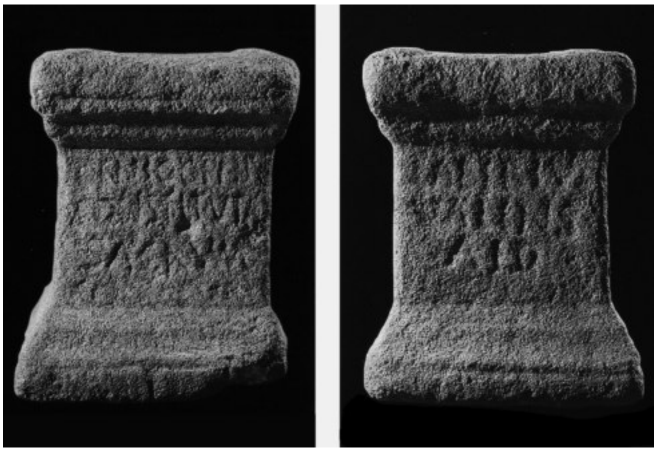

Fig. 10 Altar dedicated to the Genius of the constituted *oppidum* (National Archaeological Museum).

The fourth monument worth considering with regard to the judicial history of the town, mentioned by Armin Stylow with reference to a document written by a British officer during the Peninsular War, does not help to solve this problem either. Here is the text: *M. Iunio / Quir. Gallo / II.vir. Turrania / Cilea. Genero* (Stylow 2009: 35-46). We thus have another Ammaian *duumvir*, whose *gentilicius* is included in the name of the Eboran Senator Q. Iulius Cordus Iunius Mauricus (IRCP 414) and whose *cognomen* Gallus is of reasonable representation in *Lusitania*, one of them being the Olisiponian *duumvir* Q. Antonius Gallus, who lived at the time of Trajan (Mantas 2005: 30-31). As usual in these municipalities, we are looking at notables belonging to or associated with native families, as is apparent from the *cognomen* of Turrania Cilea, whose *gentilicius* belongs to one of the most important families of *Conimbriga*, a town where, under Vespasian, the provincial *flamen* L. Iunius Latro resided (Etienne *et al.* 1976: 49-51, 91-93). This large monument, of which a drawing is preserved, is likely to have existed in the late first century or early second century, where it probably served as the base for one of the missing statues of the *Ammaia* forum.

Undisputed is the inscription detected on the pedestal of a statue or bust, where, for the first and only time, *Ammaia*'s status of *municipium* is referred to (*CIL* II 158 = IRCP 616). This monument dates from 166 AD and has been used in the past as grounds for the identification of the town as Portalegre: *Imp. Caes. L. Aure/lio Vero Aug / divi. Antonini. f / pont. max. tri. pot/ cos. II. p. p. Municip. Ammai.* (*CIL* II 158 = IRCP 616). Unfortunately, as has been stressed many times, the monument – from which, unusually, the magistrates in office are absent, strengthening the collective message of homage to Lucius Verus (Fig. 11) – only confirms that *Ammaia* was a Latin *municipium* in the early second half of the second century. In fact, and despite this important set of inscriptions, we are still in doubt about the date when *Ammaia* ceased to be a peregrine town and rose to Latin right status, consecrated or not with the title of *municipium*. Pliny's reference to the settlements (*oppida*) awarded with the *Latium Vetus*, before the *Latium minus* was globally assigned to *Hispania* by Vespasian, may be better understood if we consider this possibility, placing the status change to *municipium* at the end of the first century, at a time when significant architectural interventions took place, as suggested by excavations in *Ammaia*, and particularly in the area of the so called south gate (Pereira 2009: 60-77, 174-175). Is it possible that the few pre-existing Latin towns opted for the title of *municipium* in order to distinguish themselves from newly promoted centres? In fact, we can only count on documentary evidence related to the *Civitas Ammaiensis* (in 44-45) and to the *Municipes Ammaienses* (166) that lacks associated dynastic references.

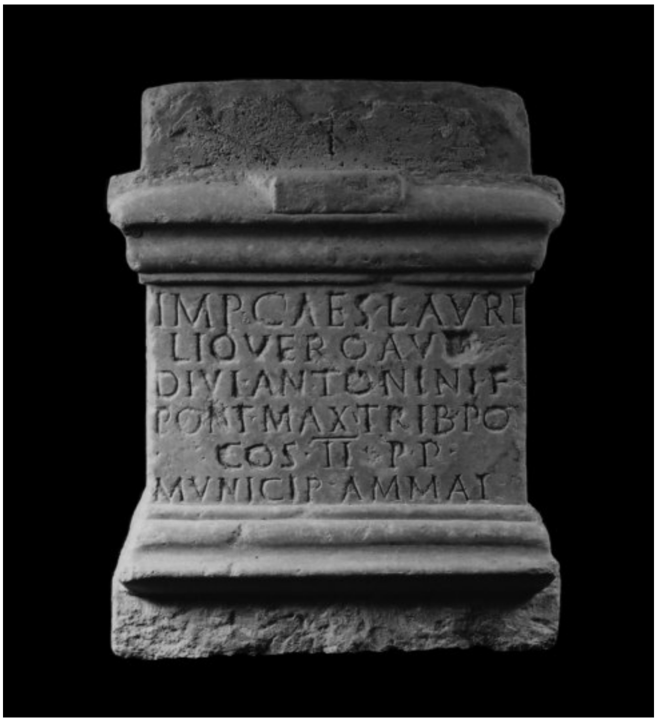

Fig. 11 Base of the monument dedicated to Lucius Verus by the *Municipes Ammaienses* (*Ammaia* Museum).

Epigraphy is also an essential source of information about Ammaian society and culture. The native anthroponymy, registered in a territory that is still vaguely defined, but covered, as we believe, much of the current District of Portalegre, does not give room for much doubt about the Lusitanian provenance of the majority of its population, clearly related to those of the Beira Interior and the region of Cáceres, and integrated into a wide, culturally well characterized area (Encarnação 1987: 167-170; Mantas 2000: 401). This circumstance is easily confirmed through the examination of surviving religious testimonies, since we have found evidence of local cults, such as the ones of *Ocrimira*, probably connected to the River Sever (IRCP 610), *Toga* (IRCP 611) and *Quanceius Tangus* (IRCP 641, *FE* 23 103, 106). Since indigenous cults are under-represented south of the River Tagus, this fact seems very significant to us.

Although, for now, only the urban temple of the forum is known as possibly being consecrated to Jupiter (Mantas 2010a: 170-181) given that S. Salvador de Aramenha has three epigraphs devoted to IOM (IRCP 605, 606, 608), this cult was widely practised by the more or less romanized native people of this region, as well as by former slaves (Mantas 2000: 405-406; Carneiro 2010 : 84-85). The epigraphy also testifies to the cult of Mars, in epigraphs from Monforte (IRCP 568) and the Tapada da Colegiada[3], the cult of the Nymphs in Monforte (IRCP 569), or of Genius related to the Ammaian *oppidum* (IRCP: 668, 693; Mantas 2004: 89-92).[4] The religious landscape corresponds perfectly to that of a widely romanized region, but where pre-Roman traditions coexist in harmony with the classic cults, with or without *interpretatio*.

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[3] According to the different interpretation proposed by Patrício Curado, to be published in *Açafa* online nº 4.

[4] The altar, consecrated to Genio Amaici, was found in Alvarrões, on the outskirts of the town.

An analysis of the Latin inscriptions also helps to detect changes in orthography, reproducing in certain circumstances the local pronunciation or a still imperfectly formed knowledge of the language, even when the supporting base is entirely classical. A survey of recorded *gentilicia* in the area that can roughly be considered dependent on *Ammaia* also offers some promising working hypotheses. Here is the current list: Aelia, Aquilia, Annia, Annonia, Carminia, Cateia, Coelia, Cornelia, Domitia, Iulia, Preccia, Propinia, Quintia, Sentia and Voconia. While some of these *gentilicia* only occur in rural settings, this does not necessarily point to a rural background, since there are several major landowners of the region among them.

The registered anthroponomical variety may indicate the relocation of families to the new urban centre, which, at the time, was built *ex-nihilo*. Some of these families belonged to a small group of notables, representing the elite that was needed to advance the programme of urbanization and to develop the political and economic dynamics that could ensure the success of the new town. These people were native peregrines, as is the case with the magistrates of the 44/45 AD epigraph, or with Publius Cornelius Macer. Some of them merely have urban representation, reflected in a limited number of inscriptions, since only Aelia, Annia and Iulia are, directly or indirectly, referred to in more than one epigraphic testimony. Without wishing to engage in a comprehensive analysis of the greater or lesser importance of these families, we must highlight Carminia, related, as has been maintained, to L. Calventius Carminius Vetus, legate of Claudius (Groag and Stein 1936: 103-104; IRCP: 677). Is this another coincidence?

The Iulia family appears in two inscriptions, suggesting a lower patronage at the beginning of the Empire when compared to other nearby urban centres, such as Évora, a fact we attribute in this area of *Lusitania* to the colonization strategy applied to the bordering stretches of the River Tagus, although it may also reflect a later engagement in the region's urbanization. One of these epigraphs, probably dating from the second half or the end of the first century, and recovered from the Quinta do Deão, recalls the provincial Flamen G. *Iulius Vegetus* (*CIL* II 160 = IRCP 617), suggesting relations with Évora or Mérida and most likely with Lisbon, where we know about a female *flamen* called Iulia Vegeta (Silva 1944: 194-195; Mantas 2004: 100-104). The second inscription, devoted to the local deity Ocrimira, records a Iulia Saturisca of clearly indigenous origins (IRCP 610). The anthroponym Iulia still occurs in two other inscriptions: in the funerary inscription for the slave child of someone named Iulia (IRCP 622), and at a small altar devoted by a peregrine Iulia to a deity whose theonym has resisted all attempts at identification. Naturally, the first two testimonies are the most representatives in terms of *gentilicia*.

In addition to the naive citizens or peregrines, epigraphy also allows us to learn something about the freedmen and slaves (Mantas 2002: 49-68), which, at this location, seem to be of completely indigenous origin. Although the freedmen always had a rather numerous epigraphic representation, and *Ammaia* presents five inscriptions that refer to them, there is a lack of Greek or Grecized anthroponyms, so common in other areas. Is it possible that the Clunians, somehow over-represented in this area south of the River Tagus (Mantas 2000: 412, 415-416), replaced the technical staff employed at the agro-pastoral and mining explorations? As for the slaves, humble as they were even in death, they are only known through two inscriptions (IRCP 622, 639). We hope that further survey work, study and much required publication will allow us to extend our knowledge about this and other historical aspects of the town of *Ammaia*, and to definitively place it among the great Luso-Roman urban centres, notwithstanding the laconic style of the literary sources.

I.4 THE TERRITORY OF *AMMAIA*: TOPOGRAPHY AND RESOURCES

D. Taelman

Introduction

This chapter presents the main results of the geoarchaeological survey conducted between 2008 and 2011 in the immediate hinterland of *Ammaia*, which studied the relationship between the Roman town and its direct exploitation territory or catchment area. The key objective was a landscape study of the town's hinterland, with particular attention for the mineral resources. In the site selection process for new towns like *Ammaia*, the availability of food and water resources was a primary concern. Besides, also mineral resources such as building stones, limestone for mortar and metal were crucial for a town's development. For this study, a site catchment analysis was performed, a method that is generally used for Prehistoric economies and that has only been applied rarely for historical periods.

Geology and geomorphology

Ammaia lies in the southernmost part of the Central-Iberian Zone, close to the Central-Iberian/Ossa-Morena transition zone (Menéndez and Azor 2006: 131). The town is part of the Castelo de Vide-Alburquerque syncline that consists of an Ordovician to Devonian sedimentary sequence (Ramirez and Menéndez 1999: 86-87; Solá *et al.* 2009: 157). The dominant rock types of the synclinal structure are pre-Variscan orthogneisses in the west, and Palaeozoic rocks (mainly shales and quartzites, and some dolomites and sandstones) in the east (Peinador Fernandes *et al.* 1973: 6-10; Correira Perdigao and Peinador Fernandes 1976: 6-10). Just a few kilometres to the north, a large, elongated, late Variscan granitic body, known as the Nisa-Alburquerque batholith, intruded the Central-Iberian/Ossa-Morena transition zone (Ramirez and Menéndez 1999: 87) (Fig. 12).

Aside from this lithological diversity, the study area is rich in mineralizations that occur disseminated in the rocks or in quartz veins (composed of milky quartz, rocks crystal or hyaline quartz). Mineralizations include gold, pyrite, uranium mineralizations, wolframite, cassiterite, barite, galena, apatite, sphalerite, and so forth) (Dekkers *et al.* 1989: 376-377; Vriend *et al.* 1991: 153-154, 157).

The territory of *Ammaia* is the hilliest part of the Alentejo region and forms the transition between the extensive Alentejo plains of the south and the Beira mountain area of

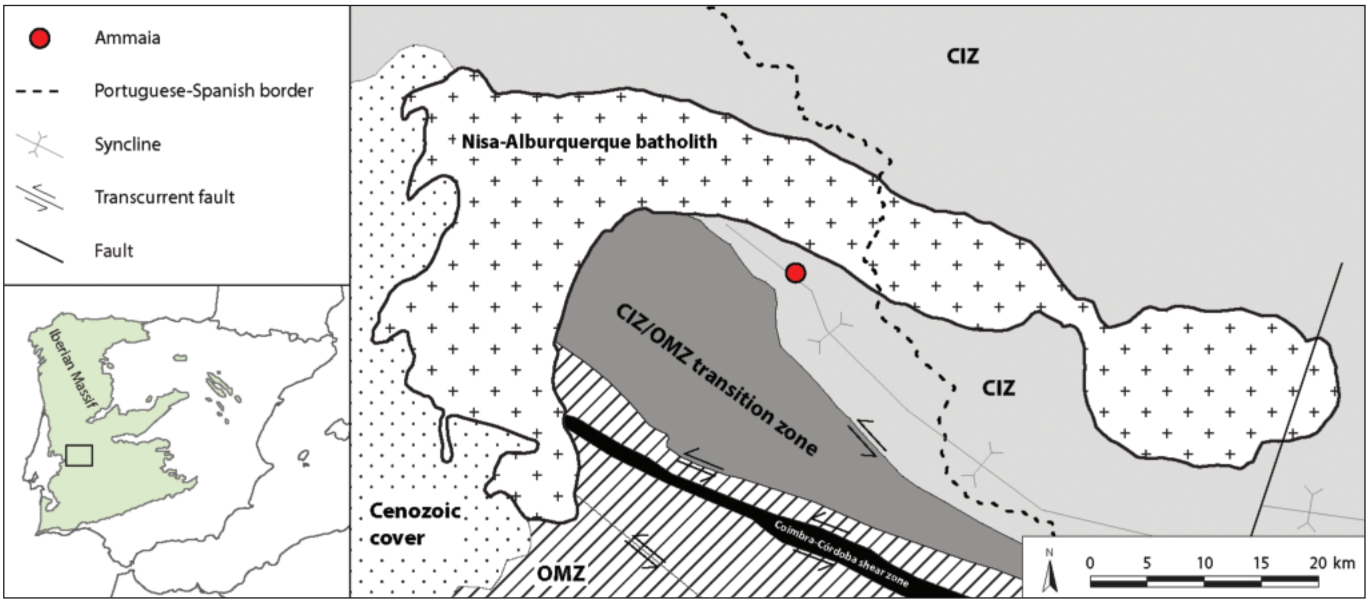

Fig. 12 Tectonostratigraphic setting of *Ammaia* (CIZ = Central-Iberian Zone, OMZ = Ossa-Morena Zone) (after Menéndez and Azor 2006; Menéndez *et al.* 2011).

the north. Vast rolling planes of schists and granite, where the bedrock lies at or very close to the surface, alternate with high and steep quartzite hills (Feio and Almeida 1980; Feio and Martins 1993; Feio and Daveau 2004; Vermeulen *et al.* 2005). Around *Ammaia* itself, the landscape is characterized by the fertile valley of the river Sever and the Serra de São Mamede, a 40km long mountain range that extends into Spanish territory with a maximum of altitude of 1027 m AMSL (Vermeulen *et al.* 2005; Deprez 2009: 5). Most of the *Ammaia* territory is dry and barren, with a Mediterranean climate with hot summers and precipitation mainly in winter (Dekkers *et al.* 1989: 377; Vriend *et al.* 1991: 154). The higher quartzite relief of the Serra de São Mamede causes abundant rainfall resulting in a significantly higher average annual precipitation than in the rest of the Alentejo (Daveau *et al.* 1977; Vermeulen *et al.* 2005; Deprez 2009: 6). The main rivers are the Ribeira da Nisa and the river Sever, both tributaries of the river Tagus (Vermeulen *et al.* 2005).

Detailed information concerning the geology and geomorphology of the *Ammaia* landscape can be found in chapter II.1 of this book.

The *Ammaia* catchment area of exploitation territory

The method of site catchment analysis (SCA) was introduced by Vita-Finzi and Higgs in 1970. They defined 'catchment area' as the area around a settlement that was exploited regularly and profitably by the settlement's occupants (Vita-Finzi and Higgs 1970). Fundamentally, SCA assumes that resource exploitation happened in an economically efficient manner and that the further a resource is located, the less likely it is exploited (Flannery 1976: 91; Metcalfe and Barlow 1992: 344).

Using GIS, the catchment area for Roman *Ammaia* was defined. For this purpose, all cartographic data (mainly topography, geology, hydrography, and so forth), as well as field survey data, were gathered in a GIS-environment. Hereafter, a cost surface was calculated based on a 30m DEM of the Alentejo region of Portugal and the Extremadura region of Spain, using the formula of Tobler (1993),

$$v = 6 * \exp(-3.5 * |S + 0.05|)$$

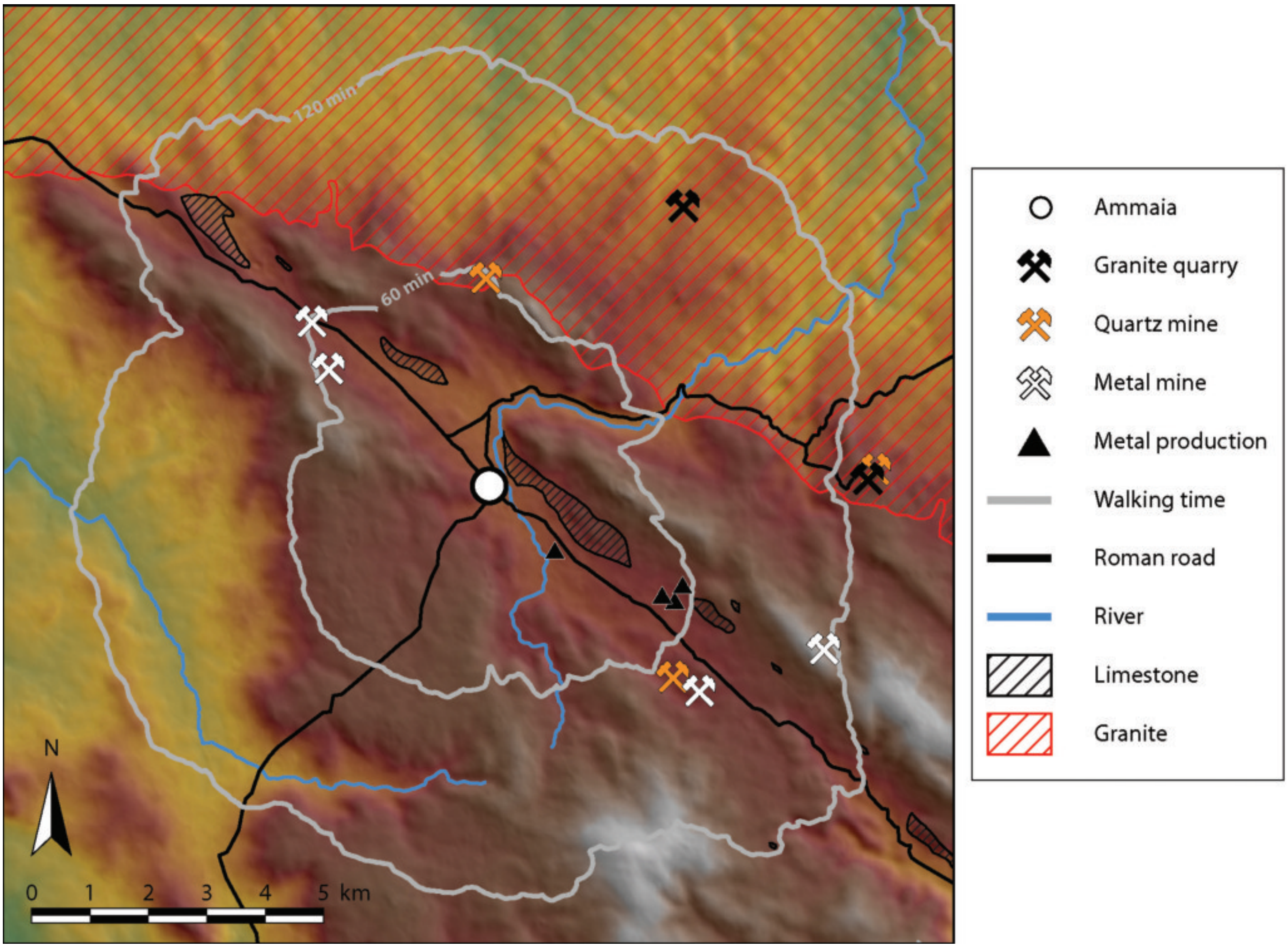

Fig. 13 *Ammaia* landscape with indication of the 60-min and 120-min walking time isochrones from *Ammaia* in relation to the principal mineral resources.

where v is the walking speed in km/h, and S is the slope in radians. Finally, the cumulative walking time from *Ammaia*, and the 60-min isochrones were determined with the urban centre as point of origin. All work was carried out with ESRI's ArcGIS 9.3 and the opensource GIS software gvSIG 1.11.0.

A visual inspection of the SCA results (Fig. 13) immediately reveals the importance of the syncline structure and of the river Sever. The central part of the syncline, with its flat planes, and the valley of the Sever form the main transportation corridor. This is also reflected by the organisation of the Roman roads leaving from the town. For this study, the area delimited by the 120-min isochrones was selected as the town's immediate catchment area. This catchment area results in a round trip of 240 minutes, leaving sufficient time for working.

Mineral resources

Granite Quarrying

Throughout *Ammaia*'s history, granite was the principal building stone for public and monumental building. Intensive geoarchaeological field surveys in the Nisa-Alburquerque granite area between 2006 and 2009 identified several potential source quarries within the town's catchment area. Of these ancient quarries, the Pitaranha quarry was identified as the principal quarry for Roman *Ammaia* (Taelman *et al.* forthcoming a). The quarry is situated near the southern limit of the Nisa-Alburquerque batholith, *c.* 9.5km E of *Ammaia* (measured along the Roman road). Evidence of ancient extraction is concentrated on the slopes of a semicircular hill that is composed of outcropping granitic rock and extends over an area of roughly 10ha with altitudes ranging between 640m AMSL and 680m AMSL. The granite landscape is dominated by boulder deposits of various sizes. As a result, the site developed into a boulder quarry with several smaller extraction spots defined by the outcrops. Block extraction was done with wedges and took advantage of the rock's natural faults (Fig. 14). Moreover, a well-designed and complex network of pathways and tracks was created to move the blocks from the extraction spot to the central processing areas and from there in direction of *Ammaia* (Taelman *et al.* forthcoming a).

In comparing the location of Pitaranha with the SCA, it is important to note that not the closest granite outcrop was selected for exploitation by the inhabitants of *Ammaia* (Fig. 13). The closest granite source is located just over 60 minutes walking, whereas, the quarry Pitaranha is located slightly more than 120 minutes walking from *Ammaia*. This indicates that the ancient stonecutters actively procured good quality granite building material for the construction of the public and monumental building complexes in *Ammaia*, even if this meant a higher transportation effort or cost.

Mortar Production

Besides building stone, mortar and plaster were crucial for the construction economy of Roman *Ammaia*. Between the 19th century and the seventies of the 20th century, limestone extraction and mortar production were the main economic activity in the Sever valley (Coelho 1988: 285-286; Oliveira *et al.* 2007: 202). Large exploitation fronts and numerous lime kilns can still be seen in Escusa and around Porto da Espada (Coelho 1988: 285-286). Unfortunately, this modern industrial extraction destroyed all traces of ancient exploitation.

Fig. 13 shows that most limestone outcrops in the territory of *Ammai*a occur at very accessible locations from the urban core, generally within a 60-minute walking time. Limestone for mortar and plaster production was thus

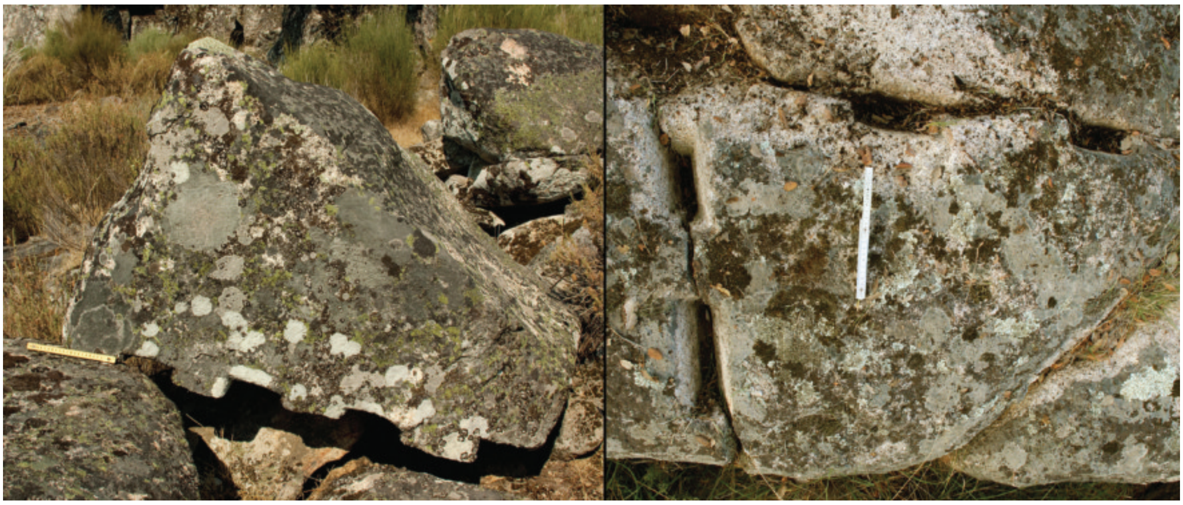

Fig. 14 Abandoned roughed-out block and in-situ semi-extracted block at the Roman granite quarry of Pitaranha (scale: 0.2m).

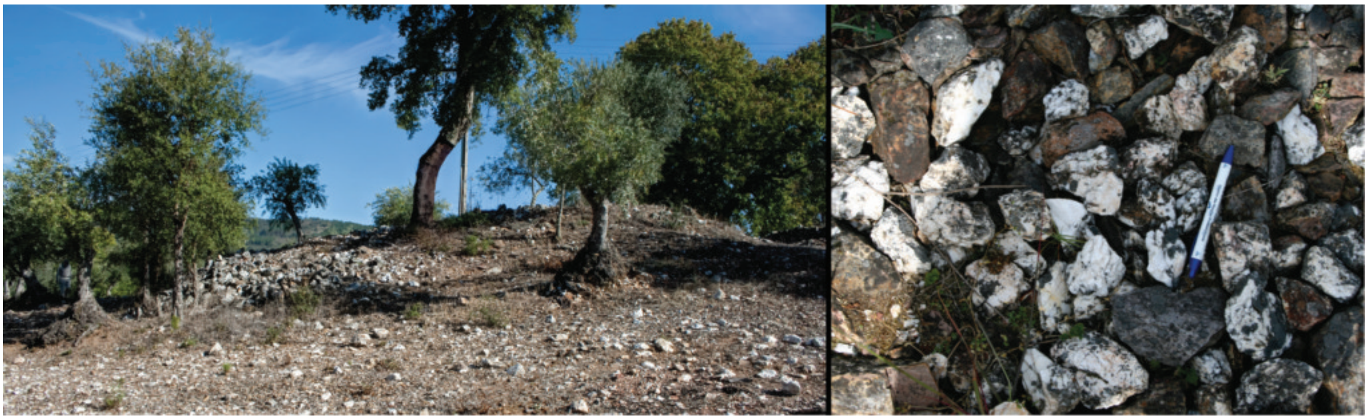

Fig. 15 Quartz debris heap at the quartz and rock crystal mining site of Naves (scale: 0,15m).

readily available in the *Ammaia* catchment area. Besides the area between Porta da Espada and Escusa, no other limestone outcrops occur in the hinterland of *Ammaia*.

Metal Mining

The richness in metals, especially iron and lead, has been known long-time and mining activities have formed an important part of the region's economy since the late Middle Ages (Pestana 1992: 207-208).

Within the catchment area, several ancient iron and lead mines and production centres have been detected. As a result of the conservative nature of mining techniques and the quasi absence of archaeologically datable material, it is difficult to date the exploitation of the metal mines. Nevertheless, as the production sites are located closer to *Ammaia* than the mines, it is likely that at least some of the sites were part of the *Ammaia* metal industry (Fig. 13).

Quartz and Rock Crystal Mining

Ammaia is also rich in quartz and rock crystal. The high importance of the mineral for the town's economy is illustrated essentially by two references to the presence of rock crystal around *Ammaia* by Pliny the Elder (*N.H.*, 37.24 and 37.127). The mineral was used mainly for the production of glass artefacts, and possibly also for the manufacturing of gemstones and luxury vessels.

Within the town's catchment area, three exploitation sites have been discovered. Large debris heaps of quartz chunks in association with outcropping quartz veins indicate large-scale extraction of the mineral at Naves (*c.* 4km SE of *Ammaia*), at the Pitaranha granite quarry (*c.* 6.5km E of *Ammaia*) and along the modern road from São Salvador da Aramenha to Marvão (*c.* 3.5km N of *Ammaia*) (Taelman *et al.* 2009: 177-180; Vermeulen and Taelman 2010: 321-322; Taelman *et al.* 2011) (Figs. 13 and 15).

Conclusion

For this study, the catchment area of *Ammaia* was determined. Moreover, an intensive survey in the town's hinterland mapped the exploitation sites of the primary mineral resources needed for the town's subsistence.

From the SCA, it is clear that the catchment area of *Ammaia* is determined essentially by the Castelo de Vide-Alburquerque syncline and the river Sever. Within this catchment area, all necessary mineral resources (building stone, metal, and lime for mortar) are readily available and easily accessible. Besides, sources of the economically important rock crystal also occur within the 120-min catchment area. The mineral richness of the immediate catchment area undoubtedly attracted the Roman settlers. Moreover, the fertile soils of the Sever valley and the high rainfall in the catchment area result in abundant water and features good agricultural properties for the immediate hinterland of *Ammaia*. This is in striking contrast to many parts of the northern Alentejo region, which aret generally characterized by rather unfertile soils and scarce water. Both the mineral richness and the satisfactory water and food supplies explain to a large extent why this specific location was selected for the foundation of the urban centre of *Ammaia*. The catchment area of town was a highly structured and heavily exploited rural landscape with several farmhouses and associated farmland, as well as with numerous places for mining and quarrying activities.

PART II

SURVEY RESULTS

II.1 GEOLOGICAL AND GEOMORPHOLOGICAL SURVEY

F. Vermeulen, M. De Dapper, P. De Paepe, D. Taelman

Introduction

For the geoarchaeological approach to *Ammaia*, designed since research on the landscape setting started here in 2001, it is essential to understand fully the geomorphology and geology of the site and its wider context. Only then can traditional field observations, intensive archaeological survey and excavation results be coherently integrated with aerial photography analysis, micro-topographic studies and a good understanding of the nature of the subsoil. During more than a decade of fieldwork in and around *Ammaia*, common efforts from different disciplines guaranteed a stimulating scientific dialogue and true interdisciplinary action between players concerned with the geoarchaeology of an abandoned town and its immediate surroundings. As most field operations were achieved in direct synergy and cooperation it was possible to approach this complex site in a coherent way, fully integrating the geological and geomorphological observations within the typical historical questionnaire of an urban survey (De Dapper *et al.* 2009: 7; Vermeulen, Corsi and De Dapper 2012). The work during these years was spread over three main phases.

Field survey campaigns in 2001 and 2002 aimed at defining the exact extent of the archaeologically vital area. This involved operations for tracing the circuit wall of the Roman town (see chapter II.4) and understanding the geomorphological essentials, such as site location preference and erosion history (Vermeulen *et al.* 2005). A long second phase of geoarchaeological research by the university teams of Ghent, Cassino and Évora[1], with a series of field campaigns between 2004 and 2011, concentrated on the exploitation of natural resources within the wider territory of the Roman town, such as water, minerals and stone (see I.2, I.4, III.2; Vermeulen *et al.* 2005; Taelman *et al.*, 2009, 2012a, 2012b and forthcoming a and b; Deprez *et al.* 2009; Corsi and Vermeulen 2012; Vermeulen, Corsi and De Dapper 2012). Finally, during the last fieldwork campaign of 2011, most attention returned to the site of the ancient town itself, where as a result of the intensive geophysical mapping of past years, there was a need to connect the formidable evidence on the near-surface archaeological structures, such as walls, streets and floors, to the situation of the soil and its erosion history. As the results from earliest operations have been sufficiently published elsewhere, or are discussed in other parts of the present book, it is predominantly on this last part of the fieldwork, which is concerned with the urban survey itself, that this chapter will focus.

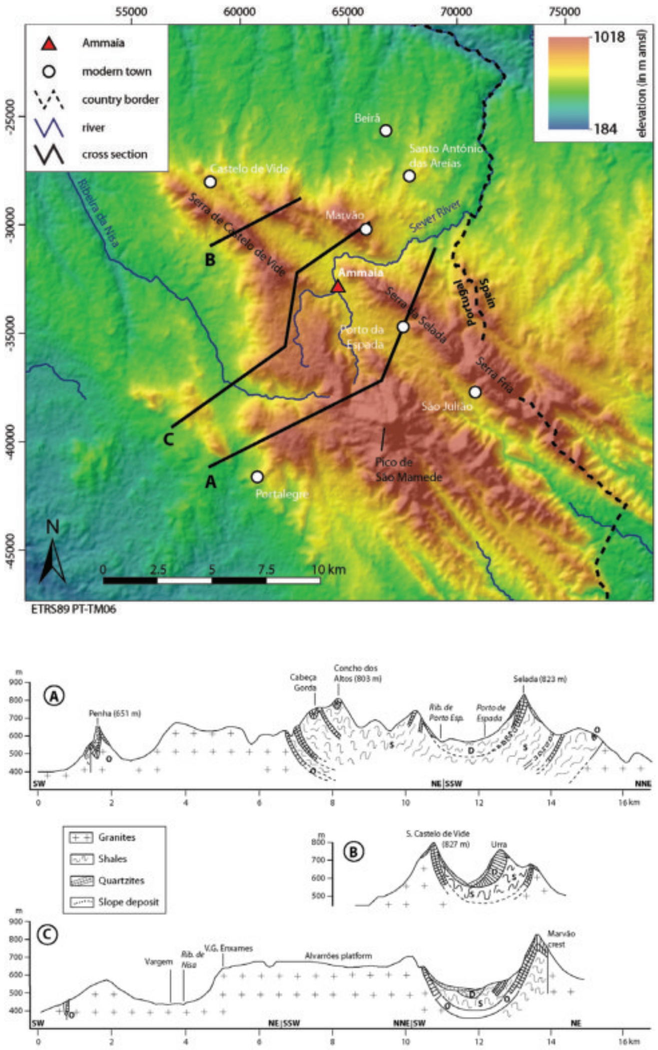

Fig. 16a-b Relief of the Serra de São Mamede and the planation surfaces in its immediate surroundings, with three cross-sections (elaboration D. Taelman).

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[1] The geoarchaeological fieldwork during this period was achieved by M. De Dapper, P. De Paepe, F. Vermeulen, S. Deprez, D. Taelman (Ghent University) and C. Corsi (Universities of Cassino and Évora). The authors appreciate much the help from geologists N. Almeida (IGESPAR), L. Lopez (University of Évora) and M. Elburg (Ghent University), from the *Fundação Cidade de Ammaia* and from the Ghent university students and collaborators during the 2011 coring operations.

Local geology, geomorphology and micro-climate

The archaeological site of *Ammaia* lies just south of the modern village of São Salvador da Aramenha, about 10km west from the present-day border between Portugal and Spain, in the heart of the Natural Park of the Serra de São Mamede (Fig. 16). The majority of this rural region of the northeastern Alentejo consists of outcropping hard rock, which means that the resulting soils are very shallow, evidently making them quite poor for agricultural purposes. This is worsened by the extreme summer dryness, so typical for this Mediterranean-Iberoatlantic climate with hot summers and moderate winters (Pope and Miranda 1999). Mean annual precipitation ranges from 500mm to 700mm and mean annual temperature ranges around 15 °C. During summer, temperature easily reaches over 40 °C but during winter, frost days are exceptional (Ratola Duarte 2002; Chazarra *et al.* 2011). This combination of poor soils and climatic conditions pushes traditional exploitation of the regional land towards grazing for meat production (mainly cows) and cork and olive production (from low demanding trees). In the Serra de São Mamede, where *Ammaia* took a central position, the climatic situation differs somewhat as a result of higher altitudes and more frequent rains. With its highest point at 1027m above mean sea level, the nearby elevated area of the Pico de São Mamede, forms a real barrier to clouds, which causes abundant orogenetic rains. Mean temperature is slightly cooler and mean annual precipitation is significantly higher compared to the rest of the Alentejo (between 800 and 1000mm). These wetter conditions result in numerous river and brooks, and generally more fertile soils. This is particularly the case in that part of the fertile valley of the River Sever, between Porto da Espada and Escusa, where the town of *Ammaia* was established (Daveau *et al.* 1977; Cerqueira, 2005; Vermeulen *et al.* 2005).

From a geological point of view, the studied area is located on the boundary of the Central–Iberian Zone (CIZ) and the Ossa–Morena Zone (OMZ), two zones of the Hesperian or Iberian Massif, a geotectonic domain that forms the oldest core of the Iberian Peninsula and occupies most of the modern Portuguese territory (Francisco Pereira *et al.* 2010). In the immediate area of the town site (Fig. 17) the visual landscape is dominated by outcrops of slates and greywackes, with occasional conglomerates, acidic volcanic rocks and limestones (Thadeu 1977; Valladares, Barba and Ugidos 2002; Rodríguez Alonso *et al.* 2004) and of shales and quartzites, with some dolomites and sandstones (Peinador Fernandes *et al.* 1973; Correira Perdigão and Peinador

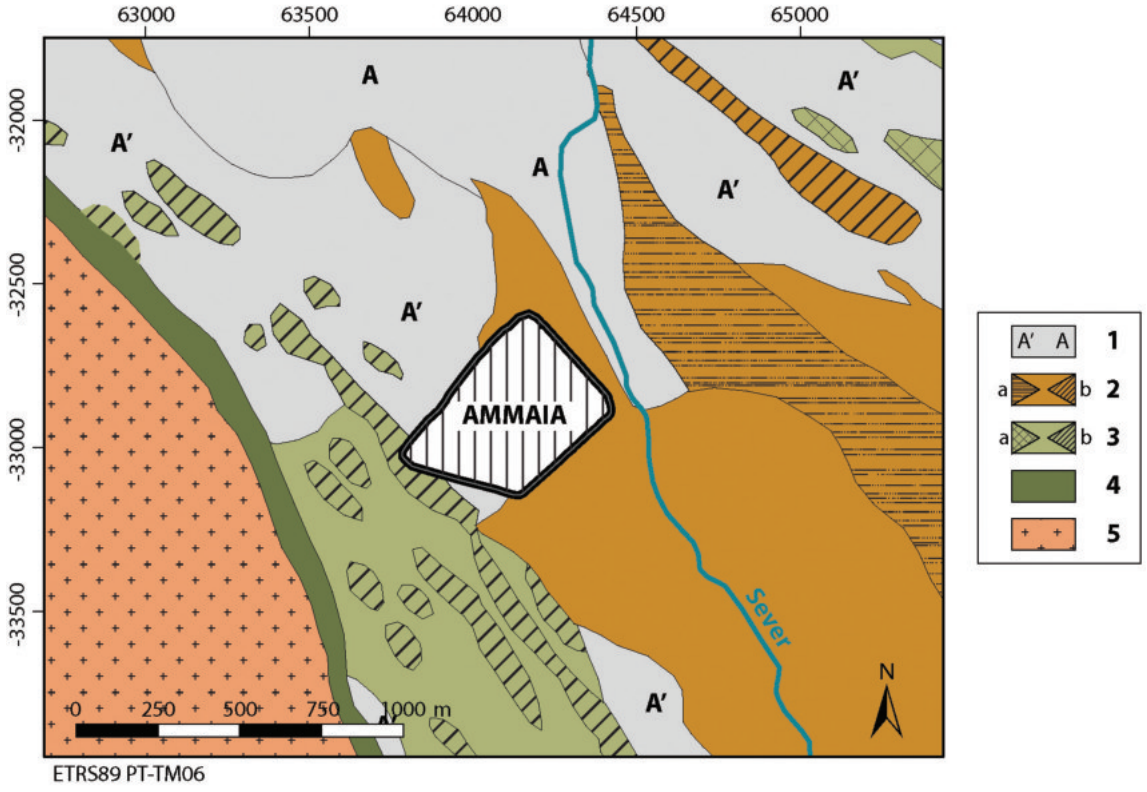

Fig. 17 Geological map of the immediate hinterland of *Ammaia*. Legend: (1) Holocene slope deposits (1A') and valley bottom deposits (1A); (2) Devonian shale, with dolomite (1b) and quartzite (1b); (2) Silurian shales, with quartzite (2a) and sometimes Monograptus (2b); (3) Ordovician quartzites; (5) pre-Hercynian granitic orthogneiss (elaboration D. Taelman after Correira Perdigão and Peinador Fernandes 1976; Peinador Fernandes *et al.*, 1973).

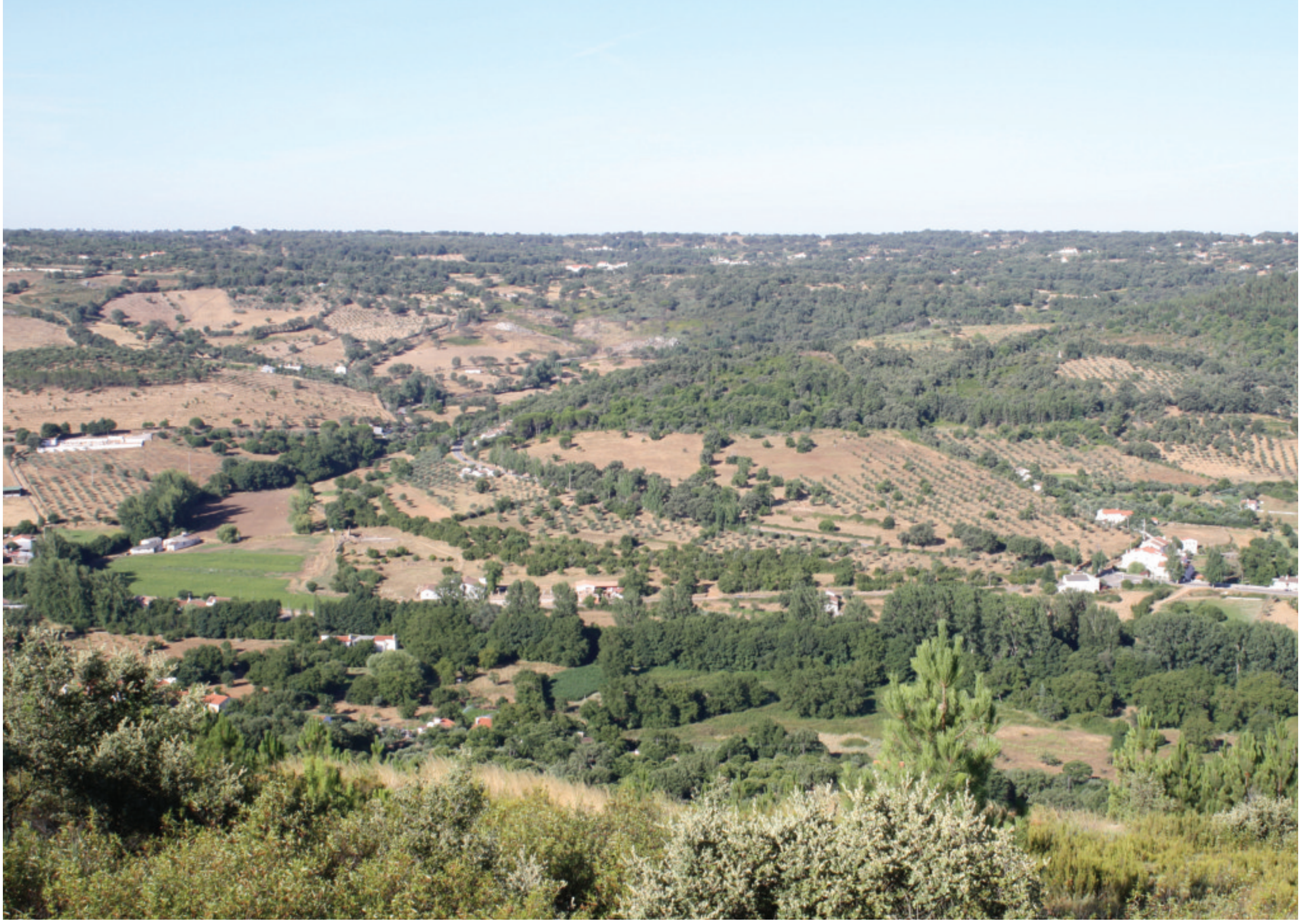

Fig. 18 View from the northeast on the hillslope of *Ammaia* (centre image) and the village centre of São Salvador da Aramenha.

Fernandes 1976; Sanderson, Roberts and McGowan 1991; Piçarra *et al.* 1999; Lopez-Moro, Murciego and Lopez-Plaza 2007). Aside from this lithological diversity, the study area is rich in mineralisations that occur disseminated in rocks and quartz veins (composed of milky quartz, rock crystal or hyaline quartz). These include mineralisations such as gold, pyrite, wolframite, cassiterite, barite, galena and apatite (Ribeiro *et al.* 1965; Vriend *et al.* 1991).

Geomorphologically the *Ammaia* site is situated in the lower parts of the Serra de São Mamede mountain range, connected in its lower part to the valley floor of the Sever River. In the immediate surroundings higher elevations occur as quartzite ridges that result from tectonic activity and a stronger weathering and erosion resistance (Feio and Almeida 1980; Feio and Martins 1993; Vermeulen *et al.* 2005). They rise approximately 250-300m above the site. The site itself lies on the gentle slopes of a small hill immediately west of the River Sever (Fig. 18). On-site elevation ranges from *c.* 525m amsl near the river to *c.* 600m amsl in the upper part of the town, which is an extension of the northwest–southeast oriented Malhadais hill. Shales form most of the town's geological substratum, except for the westernmost part where the substrate is composed of Silurian–Ordovician ferruginous sandstones (Peinador Fernandes *et al.* 1973; Correira Perdigão and Peinador Fernandes 1976).

Fieldwork results in the town area

Coring transects over the town area of Ammaia

In order to assess the near-surface geology of the site a survey by core drilling was achieved in June 2011, under the direction of M. De Dapper and P. De Paepe. A total of 37 drillings was realized by two field teams in four days. The core drillings were performed with Eijkelkamp hand auger equipment (www.eijkelkamp.com) (Fig. 19). Texture was assessed on the field by finger feeling and on sight. Colours were determined on wet (at field capacity) sediments using the Revised Standard Soil Color Charts (Japan) and the Munsell Color System (USA). The grid of drilling points were measured with differential GPS; they comprised (Fig. 20):

(1) 1 long SW-NE profile running from the foot-slope of the steeply sloping western part of the site until the channel of the river Sever (Cor 001 to Cor 026),

(2) 4 short profiles parallel to the long one but limited to the footslope (Cor 037 and Cor 038; Cor 039 and Cor 040; Cor 041 and Cor 042; Cor 043 and Cor 044),
(3) 2 short NW-SE profiles (Cor 046 to Cor 049 in the northern part of the site) (Cor 050 to Cor 053 between the *Porta Sul* and a tributary of the *Rio Sever*),
(4) two drillings (Cor 036 and Cor 045) in the area of the hypothetical theatre.

Geomorphological coring and additional archaeological observations demonstrate straightforward post-Roman stratigraphical site formation processes. Most of the site area was covered with (dark) brown, fine and loose, sandy silt colluvial sediments, deposited on top of the bedrock. The substratum is either an artificial structure, most probably part of the *Ammaia* ruins, or the geological bedrock. In most cases the bedrock consists of shale, in few cases ferruginous sandstone was found. The upper part of the bedrock is weathered by chemical and physical processes and transformed into saprolite: rotten, soft rock *in situ*. On steeper slopes the saprolite may be stripped and fresh, hard bedrock is exposed.

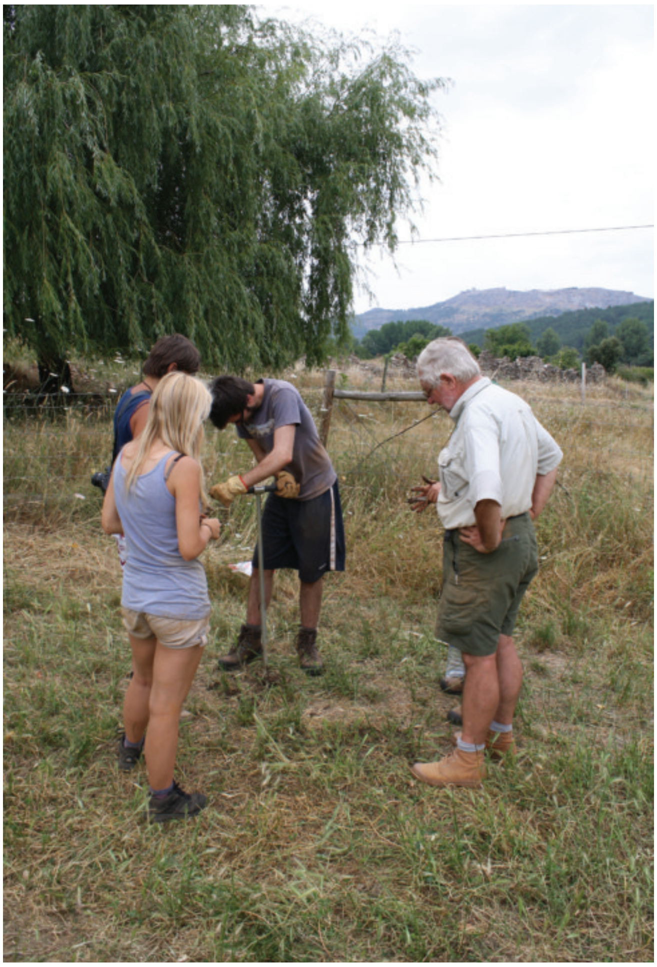

Fig. 19 The coring team in *Ammaia* with the Eijkelkamp hand auger equipment.

The steep foothill of the northwest–southeast oriented Malhadais hill was the source of the colluvial material. Fragments of the bedrock and archaeological material occur frequently in the colluvium. The latter comprise fragments of brick and tile, sherds of ceramics, mortar, iron slag, charcoal and pieces of stone foreign to the local geological bedrock such as granite... In other cases the colluvium is completely void of artefacts.

On average, the full stratigraphy is approximately 0.5m deep, with local maxima up to 1.20m. At some places, however, the bedrock is just below the earth surface, especially in the western part of the town. The upper parts of the bedrock are often transformed into saprolite as a result of deep bedrock weathering by chemical and physical processes. Near the Sever River, a 0.3m thick layer of fluvial sediments of subrounded gravel in a matrix of clayey silt were deposited by the river on top of the shale bedrock. In the transition zone between slope and valley bottom typical interfingering of colluvium and alluvium was observed. It is clear that the actual river channel of the River Sever was not wandering over the valley bottom; the alluvium is most probably the result of flashfloods after heavy rainfall or snowmelt. From this observation one can conclude that, as to the valley bottom, the present-day situation is quite similar to the past one when *Ammaia* was inhabited; it must have been possible to build in the valley bottom, provided measures against occasional inundations were taken.

Forum area observations

Thanks to the presence of several open excavation areas on and near the forum and its adjoining bath complex immediately to the south (see section I.2), stratigraphic observations allow for a more detailed insight into some of the geomorphological processes at work here, before, during and especially after the period of Roman occupation of this now abandoned townscape. Elsewhere (Vermeulen, Corsi and De Dapper 2012) we have demonstrated that this central part of the urban site, knew first a set of human interventions when the Romans developed the zone for their central square, such as the preparation of the terrain, the creation of an artificial platform and the erection of massive architecture connected with a huge building program dated around the mid-first century AD. Later on, especially from Late Roman times onwards, there is the presumed gradual shift of the site from a public centre with well kept monuments and buildings, to a probably more privatised differently used part of the shrinking town site, resulting in full abandonment and spoliation. Thereafter, the erosion of the forum site is probably part of a wider process involving the abandoned of the whole townscape.

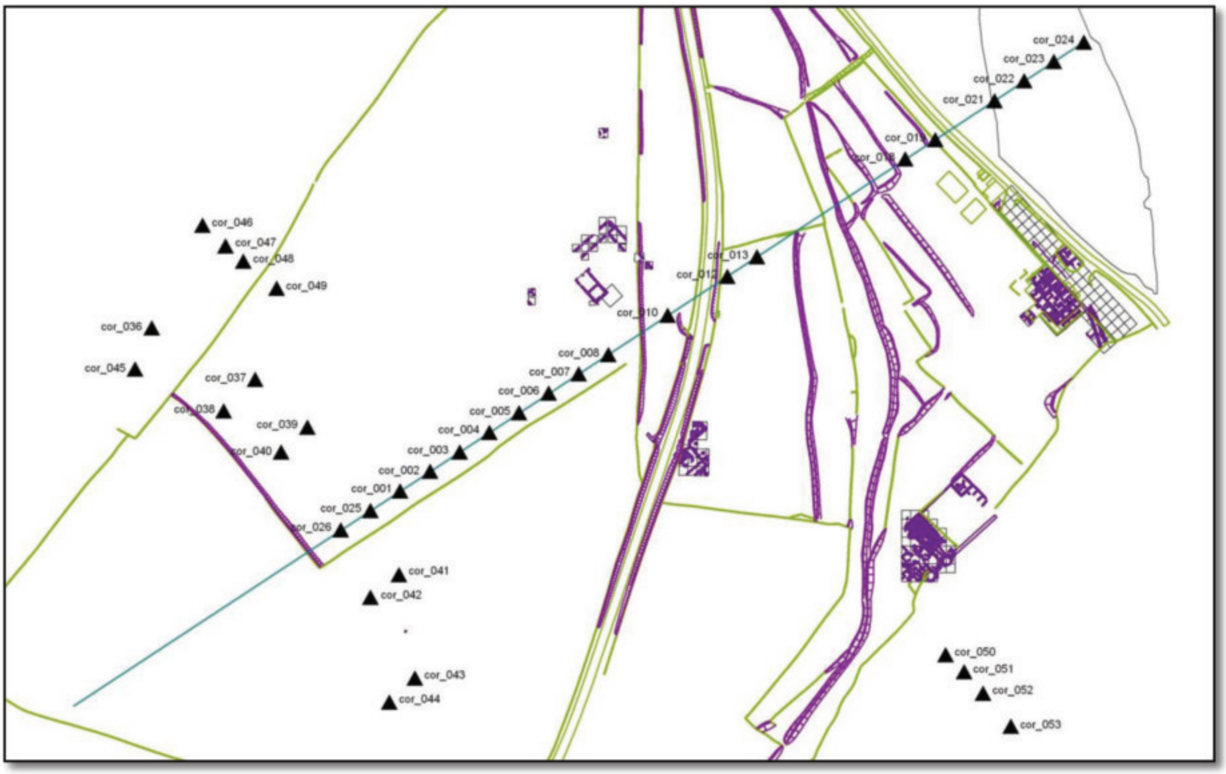

Fig. 20 Location of the coring transects in and around the intra-mural town area.

The prerequisite for such erosion and colluviation processes is an ill-maintained and poorly vegetated upslope surface. It is clear that colluvial deposits encountered in the forum area indicate the use of the former town area of *Ammaia* for agriculture during the past century, and thus further cleaning of wall rubble from the surface, as was the case until very recent times. Earlier, we observed that at the surface of the agricultural land covering the area west of the forum, there are several traces of an old terrace system for active agriculture that can still be seen today (Vermeulen *et al.* 2005). The exact date of the creation of this system cannot at present be established, but its sub-recent and recent degradation no doubt explains many of the erosion processes that occurred in the central and western part of *Ammaia*. Our earlier fieldwork in the sector of the slope immediately west of the proposed city area showed the existence of many breaches in the actual terrace walling. Heavy degrading of these field terraces in the upper part of the town area and immediately west of this sector could therefore be responsible for most of the post-Roman colluvial covering of the forum area and of other areas of the town situated to the east of it.

II.2 BUILDING A TOPOGRAPHICAL MODEL FOR THE ROMAN TOWN OF *AMMAIA*

V. Mayoral Herrera, J. A. Martínez del Pozo, E. Paliou, E. Salas Tovar

Introduction – General objectives

This contribution provides a synthesis of the extensive work done to characterize the ancient and recent topography of the site occupied by the Roman town of *Ammaia*. A thorough knowledge of this aspect of the site is considered essential for the proper interpretation of the results provided by the various survey techniques implemented on the site, and is ultimately an aspect of great importance for the understanding of its urban structure and historical evolution. First we describe the methodology used in the capture and analysis of information. Then follows an assessment of the quality and representativeness of the information obtained. Finally we explore some of the possibilities of exploitation of these quantitative data in the framework of the archaeological research of the site.

The Roman town of *Ammaia* is a good example of the possibilities and challenges of complex and extensive archaeological sites. In this context, obtaining a precise and reliable Digital Terrain Model (DTM) becomes a desirable goal in various senses. On one hand, a high quality survey is by itself a document that provides information on the general topography of the city, revealing how the urban layout has been adapted to the underlying terrain, and determining adopted solutions for the planning of public spaces, design of the street network, water supply, waste disposal etc. On the other hand, recording subtle surface variations can become an indirect means for detecting underlying structures. The availability of numerical models allows the simulation of these effects by modifying incidence light angle and the azimuth. On the other hand, other topographic variables can be derived from the model, such as slope and morphometric features, that could be useful for the detection of archaeological evidence. In this same direction, another reason that justifies the model creation is the possibility of using it to compare and join information generated from other data sources (different survey techniques) for interpretation tasks.

DTMs are also valuable tools to assess the evolution of the site. They allow the mapping of transformation suffered after the abandonment of the Roman city (terraces, land plots and irrigation ditches). It can become a useful tool for visit and planning management. From a geomorphological point of view, the availability of a DTM could be important for monitoring agents related with dynamic processes such as erosion.

Nowadays, the increasing availability of technical facilities allows an effective way to meet these objectives. Despite being a quite mechanical task, DTMs production is a decision making process that involves careful design. Problems in the acquisition, management and interpretation of data are key issues when creating a DTM.

Data sources for the topographical model

The selected procedure for generating the *Ammaia* DTM was determined by several circumstances. First, we took into account the specific field conditions derived from the layout of roads crossing the site, the fragmentation of the agricultural land plots and the type of crops. To these handicaps we must add the heterogeneity of techniques and equipments used for data production. One of our objectives was therefore to assess the quality of these data sources and their suitability to finally make a combined use of all information collected.

Topographic data for the archaeological site and the wider geographic region of the Roman town have been made available to researchers in *Ammaia* since 1995. These datasets, however, which consist mainly of contour maps, do not cover the intramural and extramural areas of the Roman town with the desired resolution and accuracy. In the summer seasons of 2009 and 2010 more systematic topographic surveys aiming specifically to serve the needs of archaeological research were carried out with a total station by members of the University of Ghent[1]. The surveys of[2] 2009 focused mainly on the wider areas of the Roman forum and baths, while in 2010 two extramural regions were surveyed: the first, located at the NE of what is believed to have been the walled part of the town, is an area with buried suburban remains, as indicated by the magnetometry results (II.6.g); the second is situated at the west of the Roman town, and possibly corresponds to the location of a Roman quarry. In addition, in 2008, 2010 and 2011 more topographic measurements were acquired during GPR surveys that covered certain limited areas of the site: the fields around the temple and the baths, the modern road that traverses the site, and a field south of the forum (II.5.c). The collection of topographic data aimed in this case to provide the necessary information for georeferencing and interpreting the results of geophysical prospection. Most data were acquired by robotic total station instruments (Leica TPS1201 and Leica TS15 I 3") tracking a prism attached to the quad used to pull the GPR sensors. The surveyed areas were on some occasions very densely sampled (sometimes reaching roughly 125 points/m^2) with theoretical accuracies of 1mm[3].

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[1] The 2009 surveys were undertaken by Michaël Dhaeyere, Sarah De Seranno, Evelien Snoeck, Devi Taelman, and Geert Verhoeven, while those carried out in 2010 by Dimitrij Mlekuž and Devi Taelman.

[2] For the 2009 and 2010 topographic surveys a Nikon DTM-520 total station was used which allows for a 3” (1mgon) accuracy angles and 3mm accuracy distance.

Building a comprehensive GNSS-assisted strategy

The fieldwork

The above mentioned topographic surveys covered restricted areas of the archaeological site with various levels of sample density, while the greater part of the Roman town remained largely unsurveyed; this made necessary the acquisition of new topographic measurements with a more homogenous distribution throughout the intra mural and part of the extramural areas of *Ammaia*. For this reason, in June 2011 a more extensive topographic survey was undertaken using a GNSS-assisted strategy. The opportunity to address this task was supported by the partnership established between CIDEHUS (University of Evora) and the Merida Institute of Archaeology in the framework of an INTERREG project focused on the use of non-destructive techniques in archaeological sites[4].

The equipment used was a double frequency GNSS receptor (model R-8 by Trimble) able of providing measurements with a typical error of around 10mm in latitude and longitude, and of 20mm in vertical. Our objective was to produce a point cloud dense and homogeneous enough to entirely cover the city outline. There was also the aim of getting data from an area of 100m around the site. In this suburbia space geophysical survey was performed looking for the identification of extramural activities like funerary or industrial areas.

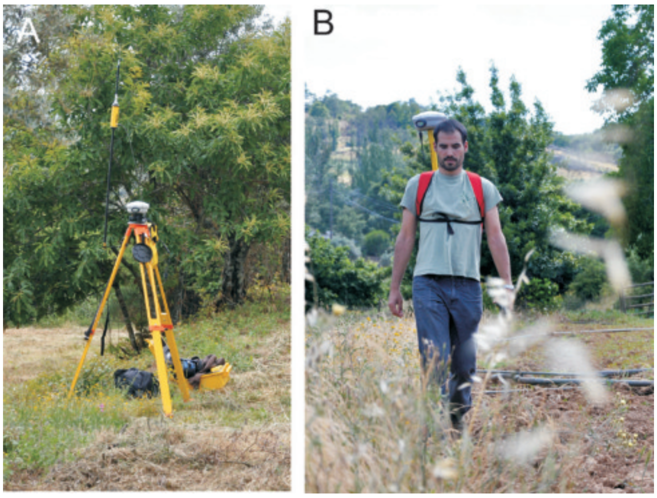

Fig. 21 Development of the data acquisition process with a backpack mounted GPS receiver.

Real Time Kinematic (RTK) survey mode was used for the data acquisition. RTK is based in the real time correction of position measurements supported by a base station located over a point of known coordinates (benchmark). The base station is continuously measuring its position and comparing itself with the known coordinates of the point, so the error in the calculation is obtained and transmitted by a radio modem to the rover antenna that is doing the topographical survey. Benchmarks of a good quality and distribution were available for the survey development all over the site.

The use of mobile receivers implies a rhythm of work that can be very different according to the surface to be covered and the method used for device transport. In our case, the total area to be surveyed was of just over 24 hectares. Given this extent, data collection using a rod-mounted unit was obviously impossible within a reasonable time. This raised the need of a massive point capture system that did not compromise the quality of the data. There are well known alternatives, ranging from the use of wheel mounted rods to the incorporation of GPS receiver units in light vehicles like a quad (see for example regarding the first option a similar work with robotic total station by Kvamme, Ernenwein and Markussen 2006). In our case the adopted solution consisted on using a backpack mounted GPS receiver. It was configured to take one point every four seconds. With the aforementioned real time method it was then possible to systematically walk through the entire site keeping a strict control of regularity of displacement, and, hence, of the homogeneous distribution of measurements. As we will discuss later, an excessive grouping and alignment of eleva-

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[3] In practice, however, there is some space for errors in data collection (latency, synchronisation error, tilt of GPR cart, etc.), as the instruments were tracking a mobile target.

[4] Trans-Frontier Research Network of Extremadura-Centro-Alentejo (RITECA). It belongs to the Operative Program of Trans-frontier Cooperation of the EU.

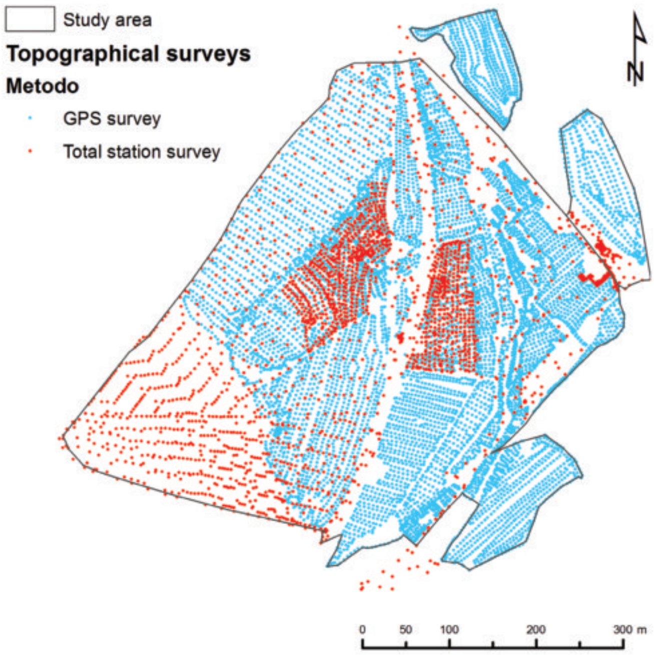

Fig. 22 The global data set for the digital terrain modelling, combining total station and DGPS elevation points.

tion points has quite dramatic effects on the quality of the models.

Generally speaking, the *Ammaia* landscape is a friendly environment for this kind of pedestrian work. Nevertheless, quality and distribution of captured data was finally determined by several factors related with terrain configuration. In the archaeological zone there are quite few plowed fields, and it is mostly covered by pasture. However, land divisions consist of very thick and wooded hedges. This inevitably implies the existence of wide strips of terrain in which was impossible to get elevation points. A similar effect was caused by the layout of the modern road that bisects the city. Evenly radical is the effect of the dense and wooded vegetation that covers the south-west corner of the perimeter wall. In this sector the only available point measurements for this part of the site derive from sampling interpolated contour lines. These contour data come from an earlier topographic survey that was carried out in 1995.

Data acquired with the GNSS station represents a number of around 9500 points distributed all over the *Ammaia* town site and its surroundings. Approximately 18 hours were invested in this task. The file containing these measurements was directly exported in text format to a GIS environment as a vectorial point file. These data were merged with the aforementioned total station points. This sample represents around 20 % of the data set. It must be stressed that this combination has yielded a very coherent result and that both data sets are highly compatible.

From the raw data to a numerical surface

The creation of a continuous elevation surface from discrete points, necessitates the application of interpolation algorithms. (Bosque Sendra 2000; Wheatley and Gillings 2002). A great number of interpolation techniques have been developed for geospatial analysis. Here, we discuss and compare two of the most commonly used: Inverse Distance Weight (IDW), and Kriging. In both cases ArcGIS 10 Spatial Analyst and Geostatistical Analyst were used. As already mentioned the choice of a suitable method of interpolation is a complex procedure that requires previous exploration of the data and depends on the experience of the GIS user. Furthermore, the quality of a DEM is also assessed according to its suitability for particular tasks (isometric visualization, specific analytical tasks, etc) (Conolly and Lake 2006:101).

IDW is a deterministic and direct method that calculates a continuous elevation surface by averaging the values of sample data points in the neighborhood of each processing cell. The closer a point is to the center of the cell being estimated, the more influence, or weight, it has in the averaging process (Villatoro, Henríquez and Sancho 2008).

In the case of the *Ammaia* model we tried adjusting the power of the function with different values (1 and 2.425 which is automatically assigned by the Geospatial Analyst tool). The main aim of tuning finely this parameter is to minimize the "bulls eyes" effect, which is a characteristic trait of this interpolation method. We looked for a compromise between controlling the appearance of this effect and getting an acceptable value of Root Mean Square Error (RMSE). It finally moved from 0.3472 with a power value of 1 and 0.2188 with a power value of 2.425). In an IDW partial model for the east part of the intra mural area of *Ammaia*, interpolated surfaces with no breaklines produced an estimated error of 0.174056. We also explored the effect of changing the number of neighbors included in the calculation, using between 10 and 15, assuring the correct distribution of the sample points. When a relatively high number (around 12) of neighboring sample points is used, the method produces a well-defined relief for the east part of the intra-mural area, where the modern terraces can clearly be seen (cf. II.5.h, Fig. 21a).

An advantage of IDW when compared to some geostatistical methods (Kriging) is that it permits the use of barriers during the interpolation process, namely breaklines that represent interruptions in the landscape such as ridges, rivers or modern roads. Breaklines limit the search for input of sample points during the interpolation process and allow only those measurements on the same side of the barrier to be considered in calculations. In this way calculations between points separated by large unsurveyed areas that may have poor or no spatial correlation are hindered. Regarding the DTM of *Ammaia* the use of breaklines corresponding to the modern roads theoretically reduces interpolation errors in unsurveyed areas and results in a model that better represents some real features (e.g roads) of the modern terrain. Such model is well suited for isometric visualisation and the 3D integration of topographic and geophysical datasets (II.6.h).

On the other hand, a disadvantage of IDW is that the DTM's accuracy cannot be fully statistically validated. As a result, the suitability of the model for certain analytical processes such as morphometric analysis and hydrological modeling cannot be easily assessed. For these tasks, kriging, a geostatistical interpolation method, was deemed more appropriate.

Kriging is grounded in the same principles of spatial autocorrelation as IDW. The main difference is the way in which Kriging assigns the weight to the points in function of the distance. Semivariogram specifically quantifies this assumption (Bosque Sendra 2000), and becomes a graphical tool used to understand the spatial structure of the data set. Kriging needs more resources and is more time con-

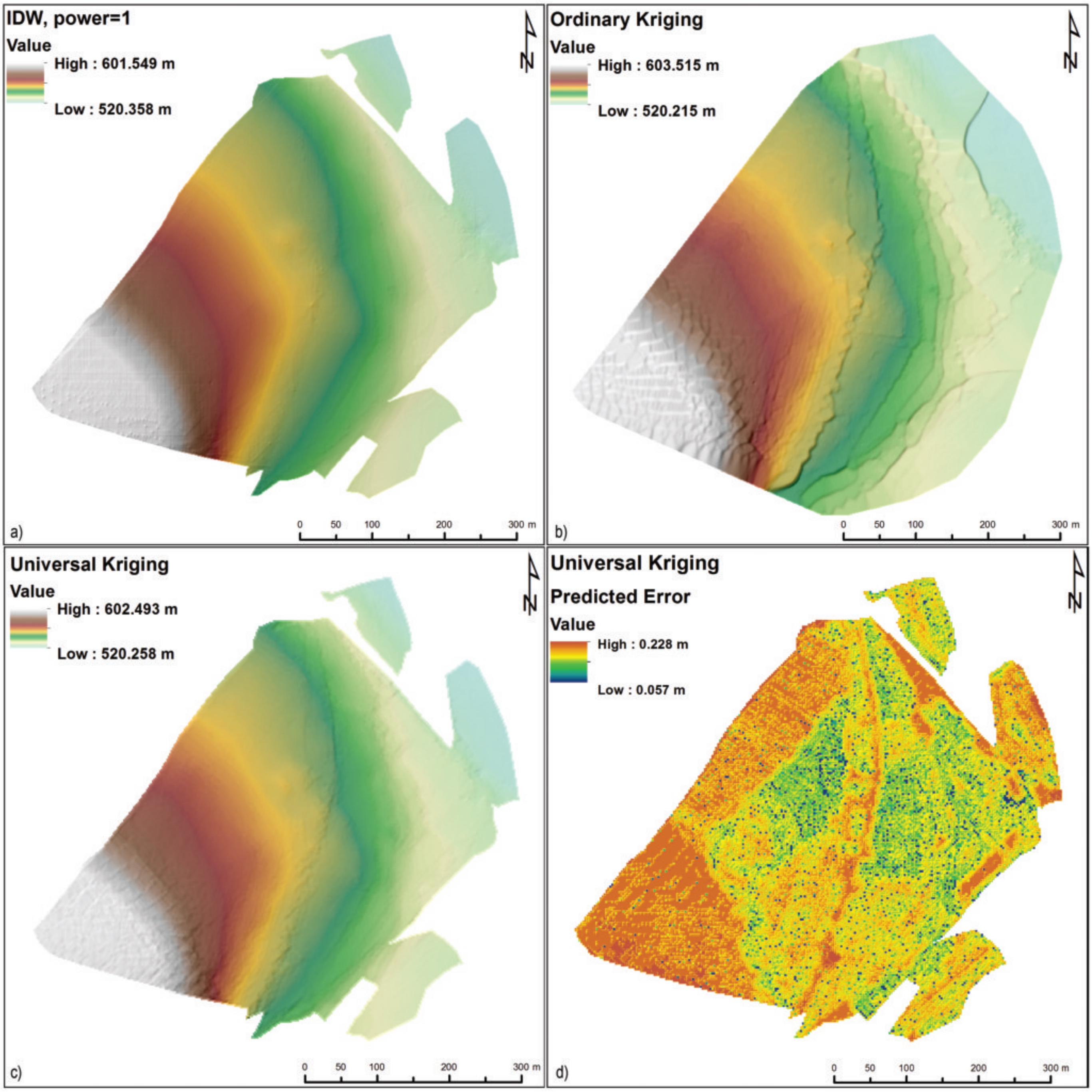

Fig. 23 a) General DTM of the city and its surrounding area generated by IDW (power function adjusted to 1).
b) Results of the application of ordinary kriging. c) Results of the application of universal kriging. d) Predicted error map of universal kriging DTM.

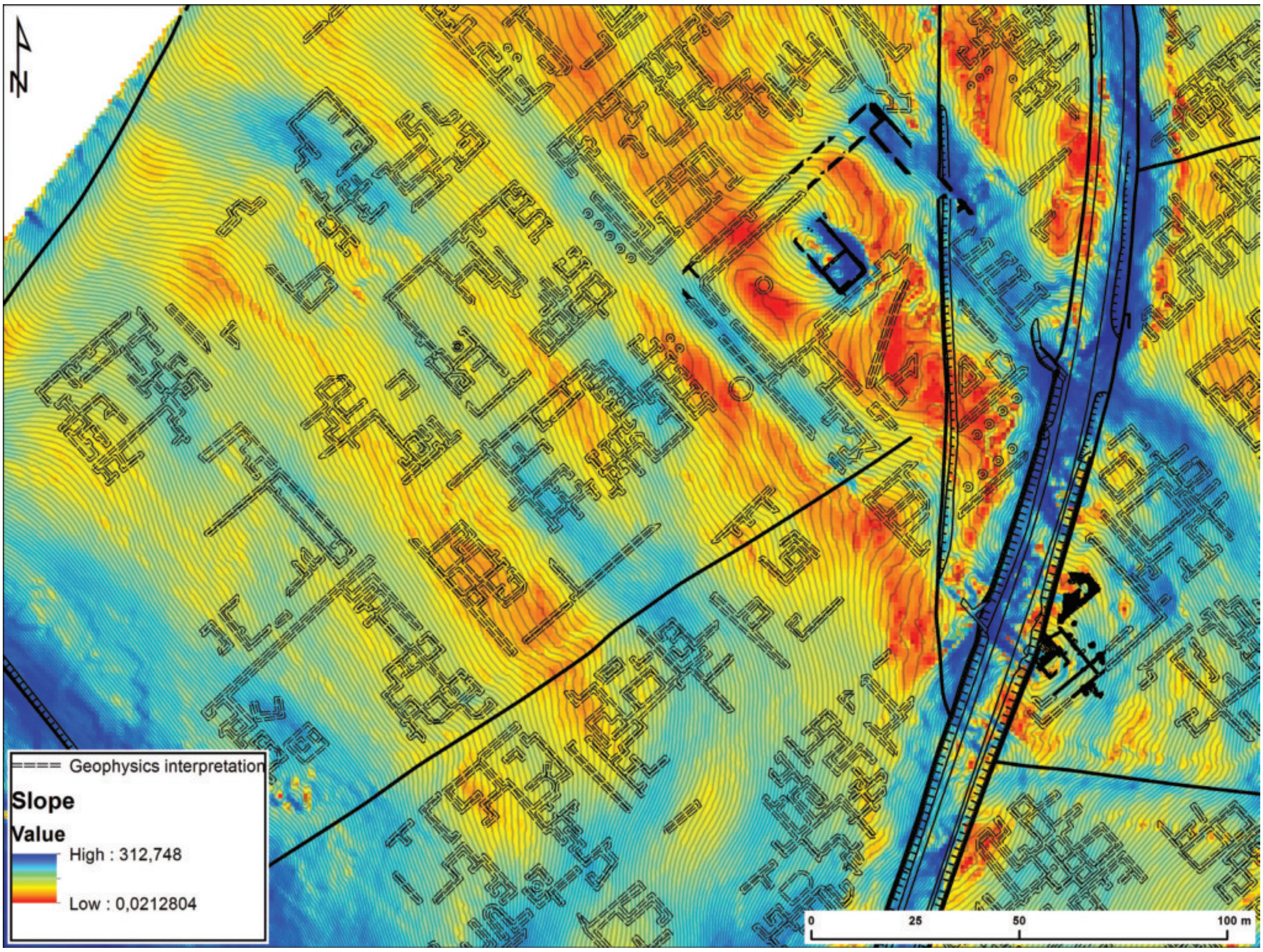

Fig. 24 Slope map derived from the DTM combined with the outline of excavated structures and the interpretation of geophysics survey.

suming than IDW, but it is able to give valuable information about the quality of the interpolated surface. The general accuracy of the model is informed by the Root Mean Squares Error (RMSE), calculated by comparing the value of the surface interpolated with the value of a set of known points that has not been used in the interpolation. Then, an idea of the reliability of the model can be assured. On the other hand, this method can also compute a map with the probabilistic error distribution all over the surface, so an interpretation of the error distribution is assessed.

In the *Ammaia* case, like with the IDW, the optimization tools of the Geospatial Analyst were used to achieve the best results. Two types of Kriging were applied, Ordinary and Universal. The former produced a very polygonal surface and was rejected (Fig. 23b). A much smoother surface was obtained by Universal Kriging (Fig. 23c). It was applied with a constant trend remove option. The number of neighbors was set up between 2-5. An exponential function for the semivariogram adjustment was selected.

The map of error distribution of Kriging interpolation shown in figure 23 (d) gives a clear idea of spatial variation of the model reliability. As a whole the result is very good, considering that extreme values (with errors reaching around 0,22m) Obviously, the poorest results corresponds to the south-western corner of the city outline, were a very small sample point was taken due to terrain restrictions. It is also clear that the best predictions were obtained in the area surrounding excavated areas of the forum and the baths, thanks to the combination of GPS and the dense coverage of total station points.

Making the most of the model: analytical possibilities

The interpolated DTM of the Roman town should be considered a beginning more than the final result in the exploration of its topography. This is an expanding and ongoing process, so we will briefly focus on the main possibilities we suggested at the beginning of this work.

A simple slope map reveals meaningful correspondences between survey results and micro-relief features. This can be clearly seen in the SW side of the forum square, and a more thorough research on this relationship could yield more results that reinforce the usefulness of topography as an information source by itself. Slope combined with analytical hill shading also seems to reveal an underlying NW-SE orientation that matches with the main orientation of the city outline, especially in the western half of the site.

Regarding the morphometric analysis, it was applied with the aim of maximizing the extraction of data from the model, in order to synthesize the complex combination of attributes that define different landforms (see Wood 1996 for a detailed description). This classification allows to define six different categories (peaks, cliffs, passes, plains, channels and pits). The calculation of results depends heavily on the window size we select to examine the relationship between each cell and its neighbours. Using a 3m window the image is quite noisy at a wide scale, but offers again a suggestive matching of channel features with the main orientation of the subsoil structures according to the interpretation of the geophysical result. Increasing the window size to 7m the alternation of channels and ridges draw very clearly the drainage structure of the area. Hydrological modeling tools offer new different perspectives of the same trends, showing an orthogonal pattern mostly erased in the eastern part of the site by post-Roman terrain changes.

Conclusions

Through a reasonably quick field and data processing work, it has been possible to produce a series of high-resolution and quality terrain models for the city of *Ammaia*. Globally the values obtained in the interpolation process (RMSE, error prediction maps) are widely assumable. In a more technical sense this work has sought a balance between the production of smooth and “natural” surfaces, and the calculation of rigorous and reliable predictions about the distribution of elevation values.

This balance leads to a variety of exploitation possibilities, ranging from the presentation of the site to the public to a detailed analysis of topography as an indirect source of archaeological evidence. However, the full development of these analytical possibilities exceeds by far the margins of this chapter.

II.3 AERIAL PHOTOGRAPHY

F. Vermeulen

Introduction

The landscape of the Serra de São Mamede, and in particular that stretch where the urban centre of *Ammaia* was located, is not very suitable for a classic approach of active aerial photography for archaeological purposes. Although the usefulness of systematic aerial photography over abandoned Roman urban sites in the Mediterranean has enough been stressed recently in a number of survey books (e.g. Ceraudo 2011; Vermeulen *et al.* 2012; Johnson and Millett 2013) and while the team investigating the site of *Ammaia* and its surrounding landscape has good experience in using oblique aerial photography from a low flying aircraft, this approach was not applied here. The limited number of arable fields in the ancient town area, together with the quite high percentage of vegetation cover unsuitable for this classic technique (olive trees, woodland, meadows, maquis…), refrained us from such a relatively costly approach. Nevertheless, two particular methods of aerial photography were possible and useful during the past years of fieldwork at *Ammaia*: the analysis of available vertical photographs from higher altitude, not taken with archaeological objectives, and the more active use of an unmanned aerial system, applied in the project only to a particular area outside the town centre. Both approaches and their results will be discussed here only briefly, as they were already treated at length elsewhere (see respectively: Corsi and Vermeulen 2008; Verhoeven, Taelman and Vermeulen 2012).

Vertical aerial photography

The aerial photography material available to analyze the site of *Ammaia* and its immediate surroundings is not spectacular. Among older aerial photographs with some historical interest, because they show the site under much less dense vegetation that today, are a few vertical black and white takes from the Instituto Português de Cartografia e Cadastro, in particular a flight from 1952 reproduced in print on a scale of circa 1/15.000. These can now be confronted with excellent recent digital and full color aerial photographs (Fig. 25) and some satellite imagery, part of which is readily available for extraction and manipulation via the Internet on such sites as Google Earth and Bing.

The main use of the vertical imagery for our archaeological purposes at *Ammaia* has been as basic documents to support the geo-archaeological fieldwork that has procured us initially with a plausible hypothesis for the exact location of the city wall. The results of this work are dealt with in the next section (II.4). The vertical images were also useful in putting forward some hypotheses about the road network linking the Roman town with its hinterland and beyond. Much still has to be learned about the Roman roads around *Ammaia* as the few available written sources and in particular the *Itinerarium Antonini*, do not mention any road connecting with the town (Alarcão 1988; Mantas 2012). A few detailed studies have recently explored the Roman road network of *Ammaia* and its territory (Carvalho 2002; Corsi and Vermeulen 2008; Carneiro 2009; Almeida *et al.* 2011) but much is still unclear, as concrete archaeological proof for well dated actual road structures remains almost inexistent. While our geophysical investigations now present good new evidence for these parts of the roads immediately linked to the walled town area (see II.5.f and II.4), much remains to be said about the exact road trajectories further away from the urban centre. This is especially evident when the geophysics show that the abandonment of the town and its

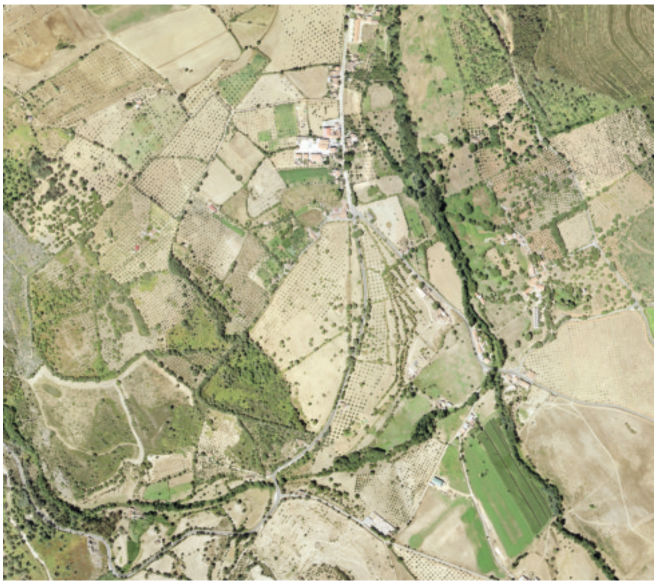

Fig. 25 Vertical aerial photograph taken in 2005 of the former urban site of *Ammaia* (courtesy of *Fundacão Cidade de Ammaia*).

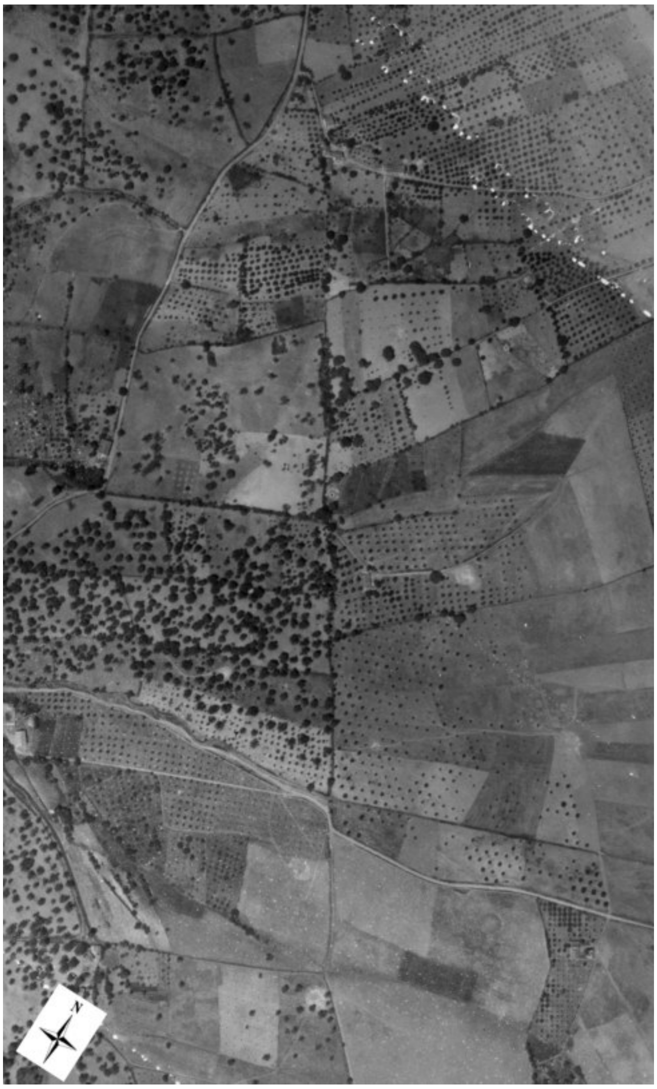

Fig. 26 Vertical photograph made in 1952 of the area north-west of the urban site, with in the center the NW-SE oriented axis dominating current land divisions. This axis is most probably a relic of the ancient Roman road leaving the town at its northern gate (courtesy of *Fundacão Cidade de Ammaia*).

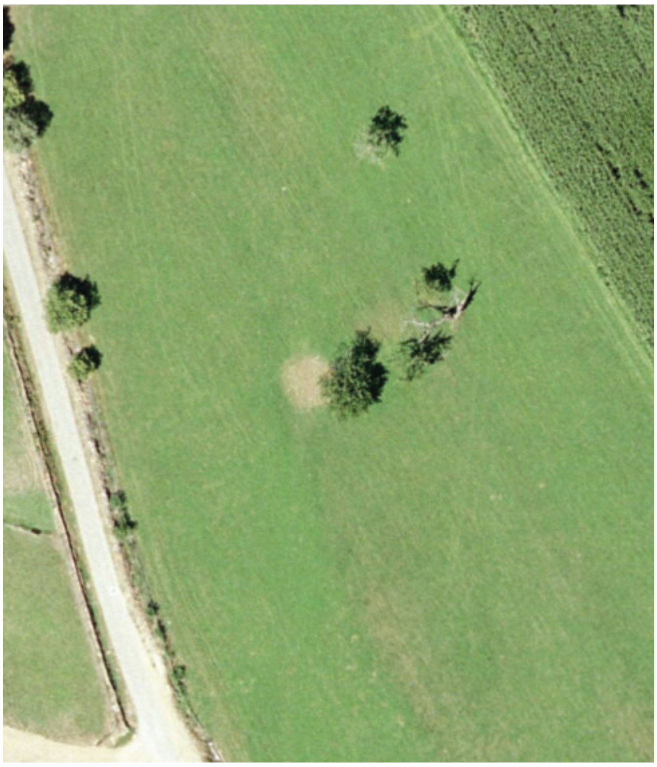

Fig. 27 Detail of the 2005 aerial photograph with in the center of the image the rectangular trace of a buried possible funerary monument along the road to *Augusta Emerita* (courtesy of *Fundacão Cidade de Ammaia*).

gates have erased this part of the ancient roads that are directly linked with the internal streets of the settlement.

Once further away from the site of *Ammaia* there seems to be more evident continuity between the Roman landscape and the one that we still observe today, especially as the road connections in this mountainous area are especially conditioned by the hilly topography. It is, therefore, logic that the vertical aerial photography of today still shows patterns of (modern) roads that have evident roots in Antiquity. This is for instance the case with the road that runs from the south gate in a southwestern direction over the *ponte de Madalena* and along the trace of the modern road to Portalegre to link the town in Roman times with western and southern *Lusitania,* or with the towns of *Olisipo* (Lisbon) and *Ebora* (Evora). Or again with another road leaving the town at the south gate and running in southeastern direction in the valley floor of the River Sever towards *Emerita Augusta* (Mérida). We will be back to these main roads that still pertain in the current landscape, after having presented all other evidence (see III.2).

Sometimes, however, it is not so much the road itself that has been preserved but a set of remarkable land divisions suggesting the former presence of a main artery that has conditioned the laying out of fields in the past. In that case often only aerial photographs allow the detection of such ancient linear features in the landscape. Such is in particular the case for the area immediately north of the once walled town zone. Our photo-interpretation leads us here to locate a suburban road leaving the city from its presumed northern gate in a straight path well marked by the current limits of properties and field boundaries (Corsi and Vermeulen 2008: 188-189). This stretch can be discerned at least for a length of some 3km towards the northwest (Fig. 26). The orientation of this road axis is perfectly consistent with a whole series of fields which lie perpendicular to it. The same photo interpretation suggests the existence of different areas of tombs located along this road, as can be suspected from the presence of traces of decaying vegetation and especially some circular and rectangular anomalies. It seems clear that this axis, which is currently only a division of the rural properties, has been the cornerstone around which agricultural exploitation was once organized, and we suggest that this coincides with the Roman developments in the area. At the present state of research, however, it is pre-

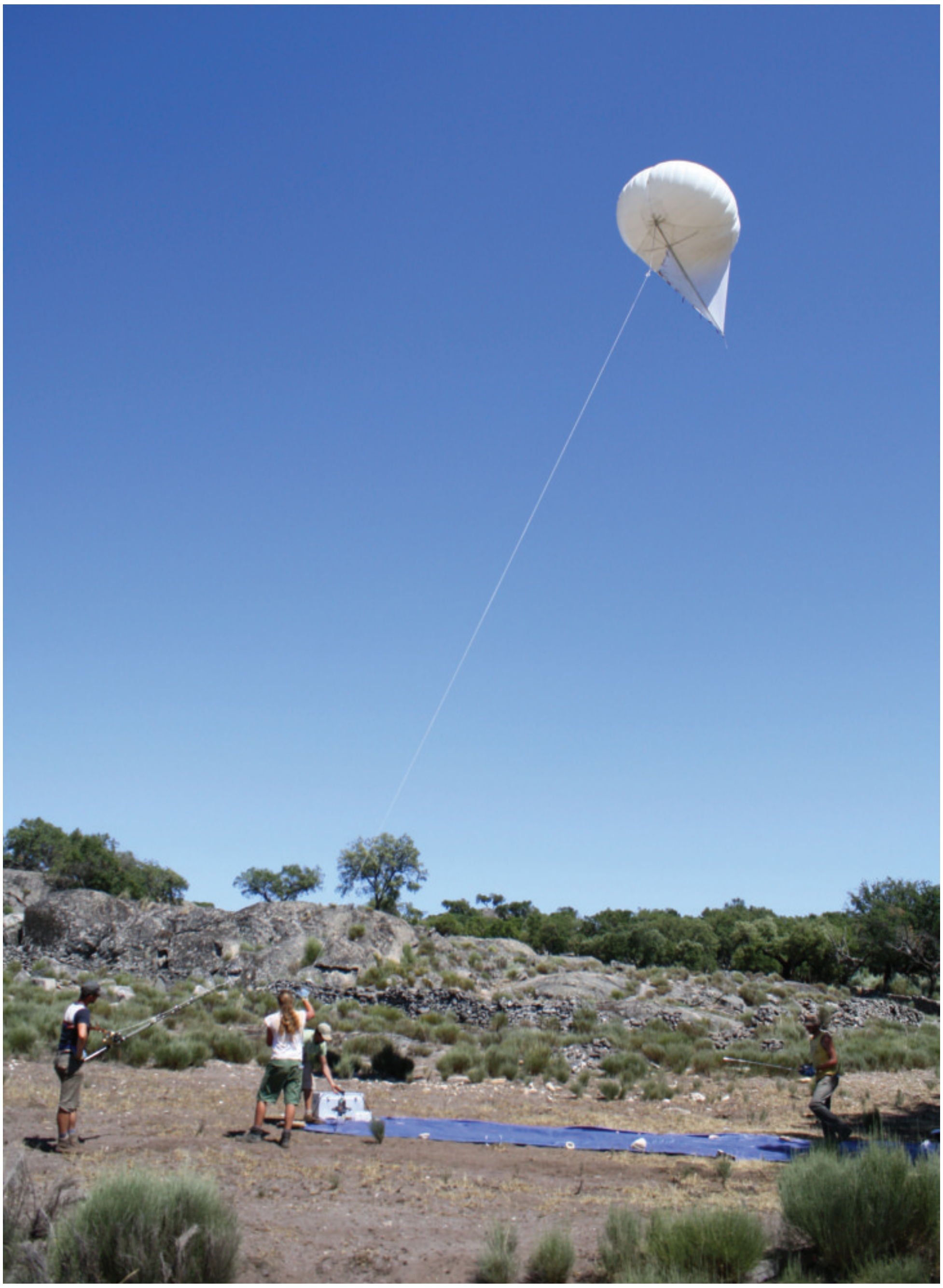

Fig. 28 Low altitude aerial photography with the helikite above the Roman quarry of *Ammaia* near Pitaranha.

mature to propose a full reading of this evidence and to put forward a modular scheme for the supposed agrarian division, which could not have been fully systematic nor consistent.

Also to the SW of the ancient city limits aerial photography suggests such a development, as we have proposed at an earlier occasion elsewhere (Corsi and Vermeulen 2008: fig. 14). Our earlier hypothetical proposals have now been recently confirmed here by way of the new geophysical surveys in the suburban areas. As we will see magnetical prospections have detected here the exact trace of the road leaving the city at its main gate, the so-called *Porta Sul*. Immediately adjacent to the road trace, as picked up here by magnetic survey, the same technique revealed structures pertaining to funerary monuments (see section II.5.f). With this knowledge in mind we recently re-studied the available aerial photographs and we can now detect on them, and especially on an image taken in 2005, several traces in the vegetation that allow us to suppose the presence of a few more monumental tombs. Some are characterized on the aerial imagery as light colored rectangular traces of vegetation photographed in a moment of serious plant stress (Fig. 27). This new information is at present only hypothetic and needs further confirmation in the field.

Helikite photography

As part of the innovative approaches applied within the *Ammaia*-project a straightforward and cost-effective hard- and software methodology was also developed for the accurate mapping of the Roman granite quarry of Pitaranha, located during surveys at some 8km east of the ancient city centre. The methodology, elaborated by G. Verhoeven and described in detail in Verhoeven *et al.* 2012, used an unmanned low-altitude aerial photography system or helikite platform (Fig. 28) developed by the Archaeology Department of Ghent University (Verhoeven *et al.* 2009), to gather aerial views of the quarry. Technological improvements in hardware configurations and state-of-the-art computer vision and photogrammetry algorithms were exploited to process the far-from-optimal airborne images. By using multiple image views from the same scene, incorporating techniques such as triangulation, a fully reliable 3D image was produced (Fig. 29).

This allowed to create a high resolution orthophoto of the whole quarry and facilitated, together with intensive fieldwork by D. Taelman, to obtain a workable interpretation of this quarry, that was of great importance for the provisioning of granite to the early Imperial city of *Ammaia* (see chapter I.4). Initial plans to also apply this technique to the urban centre were not finalized, but its potential is great and future work of this kind can still be envisaged, possibly using the new generation of drones as more performing low altitude photography platforms.

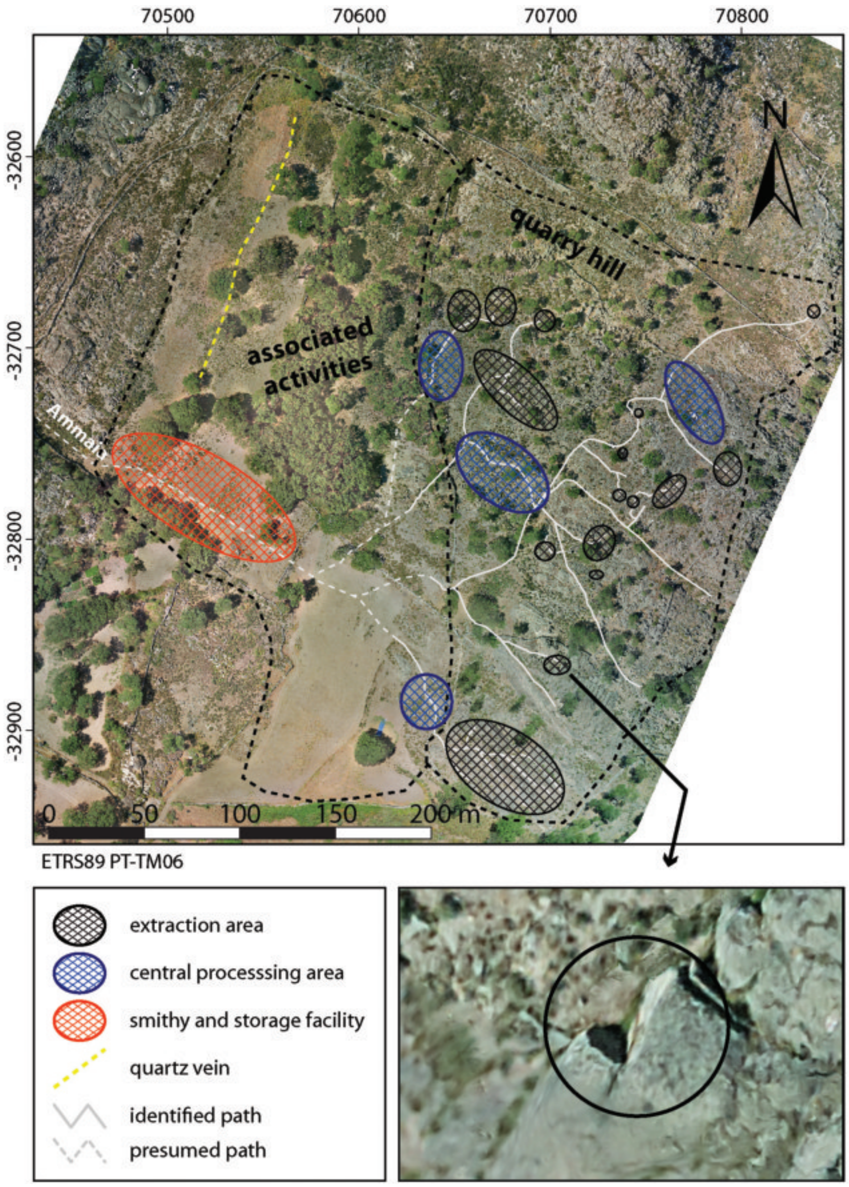

Fig. 29 Orthophotograph of the Pitaranha quarry showing the quarry hill on the right and the gently sloping and flat terrains for the associated activities on the right. The inset shows a close up of the orthograph of the exploitation front (elaboration D. Taelman).

II.4 TRACING THE CITY WALL

C. Corsi

As anticipated above (see I.2 and II.1), a hypothetical wall circuit for the town of *Ammaia* was proposed on the basis of the geoarchaeological survey, at a time when the only known segment of the walls was the stretch preserved above ground level next to the southern gate (*Porta Sul*). The proposal formulated by the joint Ghent and Cassino Universities team (Vermeulen *et al.* 2005; see II.1), based on the results of four campaigns of geoarchaeological survey (2001-2002, 2004-2005), postulated the existence of a trapezoidal perimeter with the "bases" almost perfectly NE-SW oriented, which is to say that the eastern side is parallel with the Sever river (Fig. 30). The irregularity of this shape is due mainly to the inclusion of the top and the eastern slope of the Malhadais hill, based on geomorphological observations and strategic positioning. It is in fact well documented in Roman town planning that in cases where one hill rises at the edge of a settlement, it is often included into the wall circuit to prevent an enemy attacking the city, so as to be in a dominant position and to avoid leaving open access to an ideal place for installing war machines[1].

The hill top could also have functioned as an 'acropolis' or strategic lookout, but, obviously, the gradient of this slope being on average between 11° and 17° is much too steep to allow normal building activities. Erosion has been so intensive that the bedrock outcrops almost everywhere. Soilmarks ascribed to the presence of terracing walls have been identified in the aerial photography (Corsi and Vermeulen 2008), but they could be intended just to contain the colluviation and to control the downslope flow of surface waters[2]. In this way, the total enclosed surface would have reached almost 20 hectares, for a total length of *c.* 1800m.

This "working hypothesis" was based on a full assessment of present-day terracing and field limits, on the reconstruction of the original orography, on the field survey observations and on the evaluation of the dispersion of archaeological debris (building materials, pottery, etc.), on careful mapping of still visible positive or negative remains of the wall circuit itself (mainly the stretches at both side of the south gate), and on the aerial photography interpretation (Vermeulen *et al.* 2005; Corsi and Vermeulen 2008; Corsi and Vermeulen 2009).

At that stage, apart from the uncertainty about the enclosure of the hilltop, a reconstruction was confidently proposed for the southern and eastern sides, while there was no clear evidence for the perimeter at the north-western side.

The reconstruction proposed for the SE corner was fully confirmed by the excavations carried out in 2002-2006 in the south-east corner of the circuit (Parking – excavation lot 2: Pereira 2009: 115-126; Fig. 31). In this area excavations were undertaken to establish whether the "V" shaped ditch found during the excavations in the neighboring area Parking – excavation lot 1 continued or not (Pereira 2009: 99-105). This ditch, partially overbuilt by structures whose function was not clear, has been interpreted as a sewer for runoff water (Pereira 2009: 102)[3].

The line of the walls is still outlined by the "V"-shaped ditch, where at least one drain pipe with rectangular section, passing under the wall, converged (Pereira 2009: 116). This is further proof that the drainage system was set before the construction of the walls. The archaeological finds inside the filling of the ditch date to the period between the Flavian dynasty and the reign of Trajan, but the initial excavation of the ditch is thought to have been carried out earlier, possibly during the first half of the first century AD or the reign of Claudius at the latest (Pereira 2009: 116). Segments of the city walls were seen also in excavation lot 1 of the parking area, under the existing delimiting wall of the courtyard of the "Quinta do Deão", where they still function as foundation of the modern wall delimiting the garden of this sub-recent farmhouse. In total, this Roman wall fragment is preserved for a length of more than 20m and a maximum height of less than 2m (Figs. 32-33). Its thickness is not huge: only 1.20m. The wall is built in *opus incertum*, with irregular blocks of granite. The wall is built here on the levelled schist bedrock, with the foundations made only of a mixture of pebbles and mortar. These foundations project on average only 0.15-0.20m from the facing of the wall on both sides (Pereira 2009: 119).

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[1] The closest comparison for the inclusion of the hilltop in the wall circuit is the case of *Baelo Claudia* in *Baetica*: Sillières 1997.

[2] As we will see better later (section III.1.a), this slope could also have been used for the installation of a theatre.

[3] This ditch was connected with other sewers that run under the walls from the housing sector partially excavated inside the Quinta do Deão (see *supra*, chapter I.2 and Pereira 2009: 100).

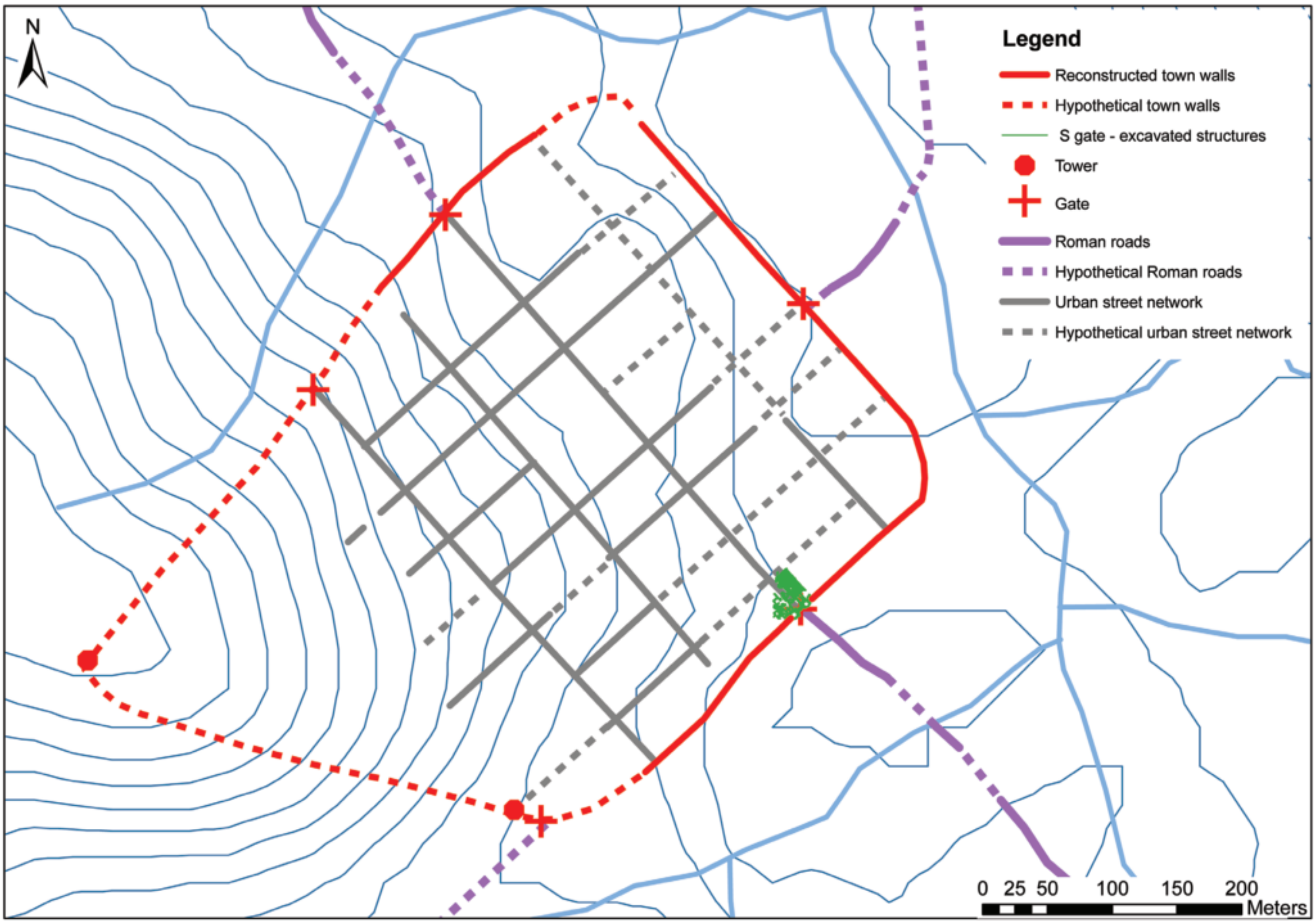

Fig. 30 Hypothetical reconstruction of the wall circuit of *Ammaia* on the base of modern topography, with indication of possible gates and reconstruction of the urban and suburban road network (elaboration C. Corsi).

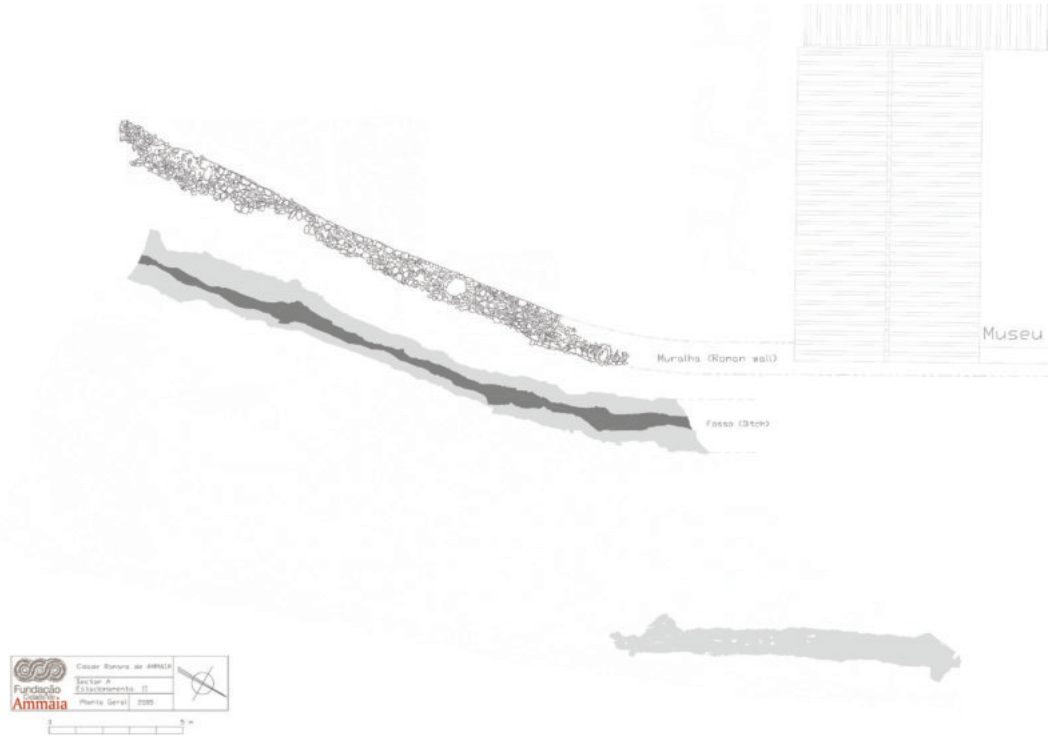

Fig. 31 General plan of the excavations in the Parking lot 2 (© *Fundacão Cidade de Ammaia* 2006).

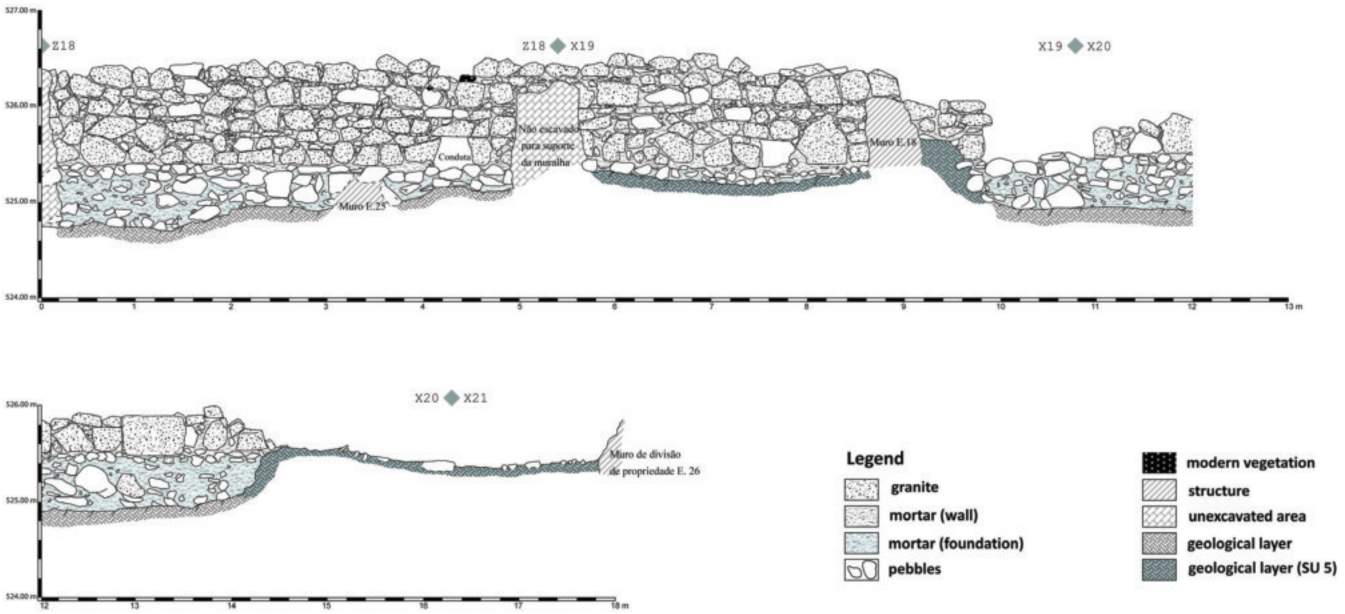

Fig. 32 Prospect of the segment of *Ammaia*'s city walls preserved under the delimiting wall of a modern property in the excavation sector named Parking lot 1 (© *Fundacão Cidade de Ammaia* 2006).

The erection of the walls is thought to have been carried out between the reign of Claudius and the beginning of the Flavian age (Pereira 2009: 104, 120). Later phases possibly took place in Late Antiquity: to the fifth century is dated the addition to the walls, with the function of containing the embankment *intra-muros*. This addition is characterized by a completely different, and "rougher", technique of schist slabs without mortar (width 1.50m), which is probably a restoration of the existing (and disrupting) wall circuit (Pereira 2009: 120-121). The frequenting of the area during this phase is proved by the finds of sherds dated to the fifth century and later, probably connected with the spoliation of the wall itself.

In this way the walls of *Ammaia* would be, together with those of *Conimbriga*, the very few early Imperial town walls known in *Lusitania*, as most of the others are attributed to a mid Imperial if not Late Roman date (De Man 2011).

Further confirmations and integrations of that first proposal, linked to the early geo-archaeological approach, resulted from the recent geomagnetic survey (see II.5.b). The latter, in fact, offers some additional (but still not conclusive) evidence for the northern corner of the wall circuit, where it is probable that the bend of the line of the walls is consistent with the position of the modern crossroads. Furthermore, the stretch of wall along the south-eastern limit, well marked by the presence of the imposing *Porta Sul*, is detectable via the survey interpretation in many places (e.g., magnetic anomalies 165, 168, 172, 179-180). The trend of the curve on the southern corner (magnetic anomalies 141, 160) leaves open the possibility that the wall continued north-westwards to link with the (postulated) opposite line north of Block IV, running along the foot of the hill, or that it climbed northwards to reach the hilltop and enclose it.

The magnetic anomaly no. 141, at the edge of Block XXXIV is very peculiar in shape, and could be interpreted as a functional structure (a kind of tower?).

Apart from the existence of at least one tower, postulated on the basis of the geoarchaeological survey (Vermeulen *et al.* 2005), very interesting data come from the magnetic survey. Anomaly no. 168 is interpreted as part of a tower abutting on the line of the walls, and the same could be said about magnetic anomaly 99 on the eastern side.

No less than three gates were probably incorporated in the wall circuit: the well-preserved southern gate (*Porta Sul*), the northeastern "river gate", where the *decumanus* running along the southern side of the forum must have exited the town and linked to the road leading towards the riverside identified in the extramural survey, and another gate situated on the northwestern side of the towns, opposite *Porta Sul*. Here the extra-mural geomagnetic survey has shown that a major road connected the town to important cities in *Lusitania*, one in the direction of *Norba Ceasarina* (Cáceres), along the valley of the river Sever, and one in the direction of *Olisipo* (Lisbon) (see: section II.5.f).

These gates are positioned where the main axes of the urban layout cross the wall, as is the case of the *cardo* flanking the eastern side of the forum and the *decumanus* running between the forum and the thermal baths (Fig. 30).

To these three more important gates, some "secondary" ones could be added: a *posterula* possibly opened at the northern crossing of the *decumanus* A and the walls, where the presence of a quarry (see II.5.f) suggests the existence of an easy connection to transfer building stone inside the walled area. A second *posterula* can be located at the south-

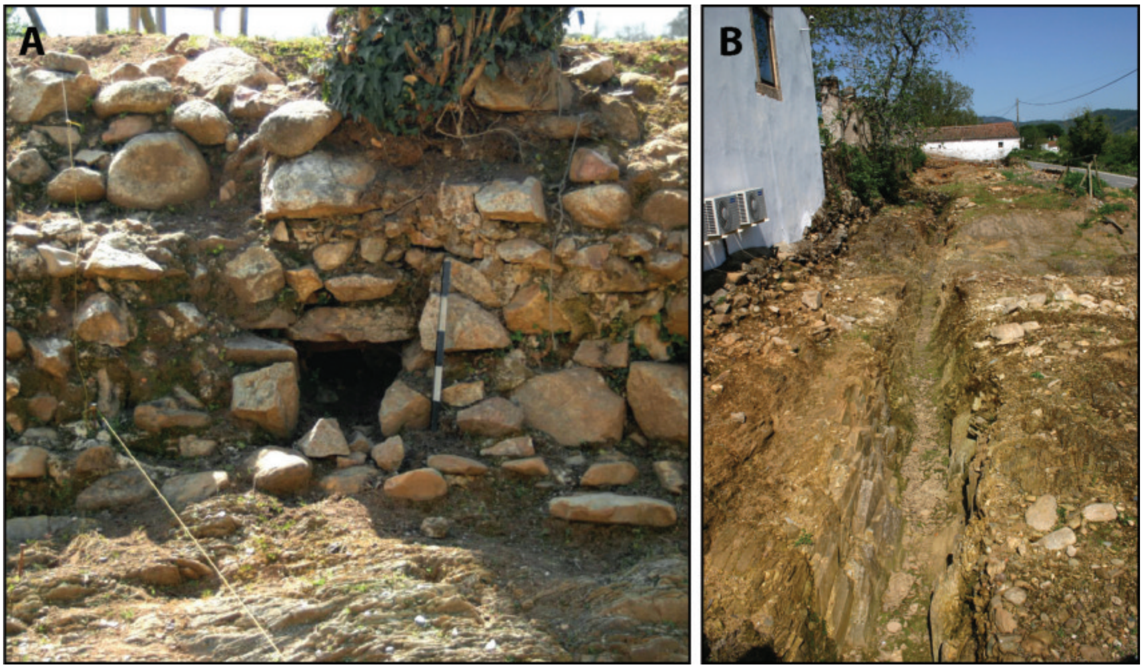

Fig. 33 (A) Sewer opening in the town wall in the area of *insula* XXXVIII (scale: 0,50m); (B) V-shaped ditch serving as the main drainage channel for the town (excavated near the museum). (Photo's by J. Carvalho and S. Deprez). The segment of *Ammaia*'s city walls brought to light in the south-eastern corner of the circuit during the excavation campaigns 2002-2006 (© *Fundacão Cidade de Ammaia* 2006).

western rounded corner of the walls, where the presence of several buildings just outside the walls (one possibly a funerary monuments: see II.5.b, magnetic anomaly 181) can be considered as an indication of a suburban road.

The preserved version of the monumental south gate presents two round towers flanking the wide entrance. As anticipated, the total revision of the excavations carried out in the area of *Porta Sul* (Fig. 34), together with a new stratigraphical analysis of the preserved walls, will be published soon (see I.1), so we won't go deeper into the study of the structures here. However, we can advance some propositions for comparative research about this type of round tower. Indeed, the two round towers flanking the south gate can be ascribed to the type of structures which "interrupt the line of the walls" (Varene 1987: 20), and for shape, dimensions and general organization of the whole structure of the gate, they can be paralleled with the gate of the road *de Roquemaure* at Orange (Magdinier and Thollard 1987: 80-81), but also the *Porta Boiano* in *Saepinum* (Italy: Rebecchi 1987). The wall circuit of the military colony of *Aurasium* would have been built around 20 years after the foundation of the colony, that is *c.* 15 BC, together with the one of Nîmes (Magdinier and Thollard: 90), and a similar chronology is attributed hypothetically to the foundation and erection of walls of *Augusta Emerita*, *Caesarugusta*, *Ilici* (Elche), *Iuliobriga*, *Lucus Augusti* and *Bracara Augusta* (Martín Bueno 1987: 109). The construction of the gate of the sannite town is undertaken during Tiberian reign (Rebecchi 1987: 142-144).

There are possible suggestions of a tower further to the southwest along the south-eastern side of the city, alongside Block XL, but in this case the tower looks squared. During the geoarchaeological survey the presence of a tower was also suggested on the hilltop of the Malhadais hill, but its shape could not be determined (Vermeulen *et al.* 2005).

Concerning the chronology of the whole wall circuit, we can accept the one proposed earlier, around the mid first century AD, considering that no new evidence is provided by the survey. It is is interesting to note that that the walls were built in a second stage after the first settlement, as is documented by the excavations in square Z18 of the Parking area (Pereira 2009: 119). Here the wall "E21", destroyed and levelled to up to the level of the foundations in a second phase, appears to be built upon the layer identified as the oldest in the stratigraphy of the area, dated to the early first century AD. It is remarkable that this segment of wall already presents the NE-SW orientation that is totally predominant in the structures of the intra-mural town (see section III.1.a).

It is therefore interesting to enucleate the steps that were taken to design and built the Roman town. It is, in fact, clear, that in first instance surveyors tracked alignments and delimitated the perimeter of the town. The city-walls were not built immediately but the "V" shaped ditch that served for water drainage was used as marker. Together with the ditch the sewer system was soon implemented. Some struc-

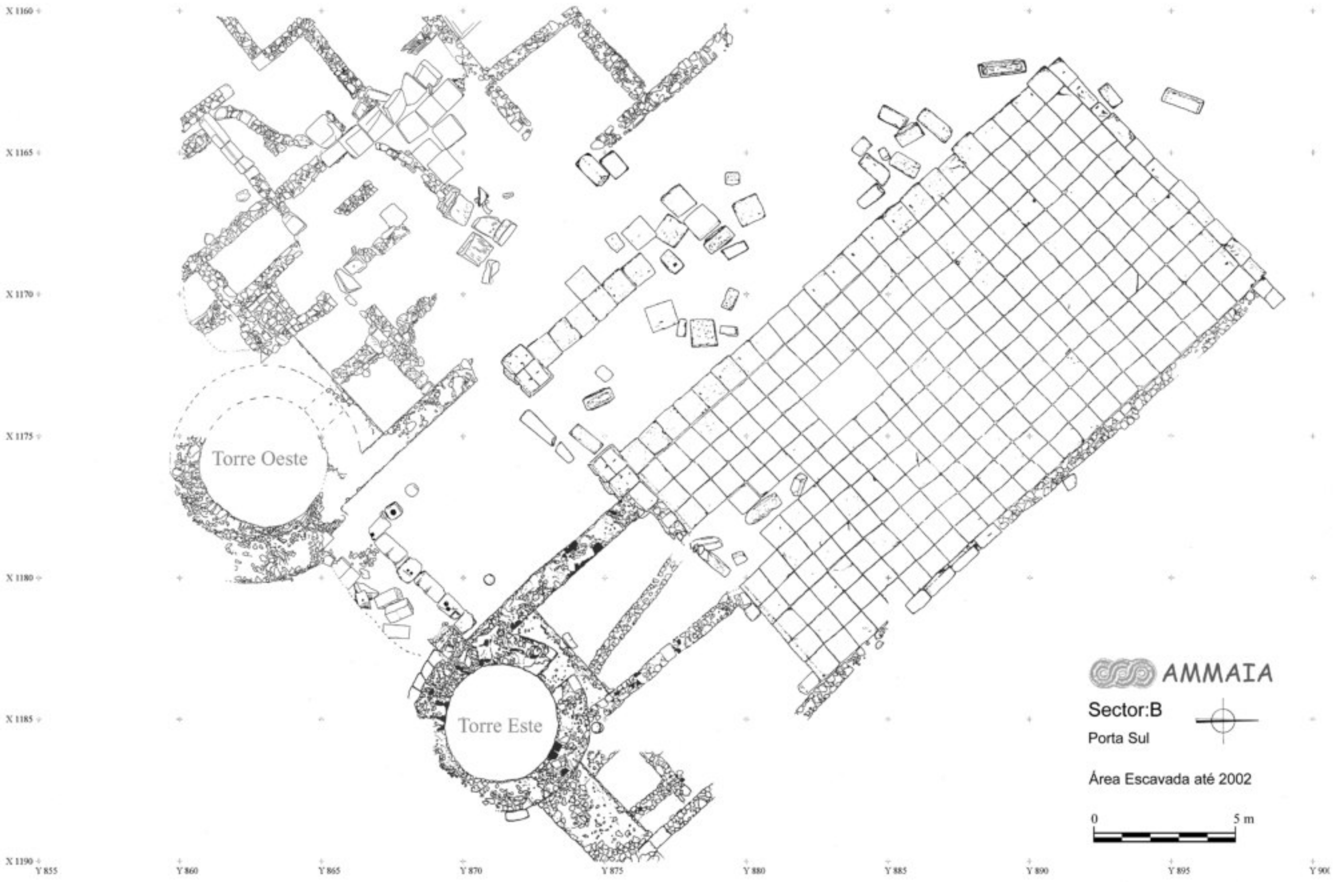

Fig. 34 *Ammaia*. Plan of the south gate (*Porta Sul*) at the end of excavations in 2002 ((© *Fundacão Cidade de Ammaia* 2002).

tures were built soon after tracing the layout of the town, but most of them were replaced by other constructions, after a time span that should be shorter than 20 years. Only around 50 years after the foundation, during the most important monumentalisation phase at *Ammaia*, the city walls were built.

II. 5 GEOPHYSICAL PROSPECTION

II.5.A STRATEGIES AND PLANNING

F. Vermeulen, C. Corsi, C. Meyer, P. S. Johnson, B. Slapšak, L. Verdonck, J. Verhegge

Introduction

During the 1990s it was gradually realised among archaeologists studying large sites, such as urban settlements of the Classical periods, that a series of large scale survey techniques held out the promise of making a major contribution to our understanding of urbanization in Antiquity. This was spurred by seminal projects, such as the study of Boeotian towns by Bintliff and Snodgrass (1988), as well as by the refinement of geophysical techniques that could be used for the fine-grained analysis required to bring out details of urban layout. The consequence of a series of developments, especially in the fields of geophysical survey, aerial photography, artifact surveys and GIS-analysis, has been an upsurge in the non-destructive survey of urban sites, all over the Mediterranean. Archaeologists have especially been quick to realize the potential offered by geophysical techniques and instruments. Large and complex urban sites which had hitherto been studied in a piecemeal approach, largely predicated upon the monument-based interests of earlier scholars were now subject to survey techniques that could rapidly generate plans of partial, or in some cases, complete townscapes, most notably at such sites as *Falerii Novi* and *Italica* (Keay 1995; Keay *et al.* 2000). This has led to a revolution in how urban sites are approached, with survey techniques being used increasingly to generate plans of towns prior to excavation as a way of ensuring that the excavation can be used to address site-specific questions in a way that had not been possible before, and also in many instances as a replacement for destructive field interventions. Recently, several collective publications have presented a whole series of large field projects focusing on an integrated survey of whole ancient cityscapes, both in eastern and western Mediterranean (Börner, Uhlirz and Dollhofer 2012: 57-121; Vermeulen *et al.* 2012; Johnson and Millett 2012)

During this process, research has begun to reveal the advantages of integrating a range of different geophysical techniques on such urban sites, choosing the most appropriate suite of approaches for the nature of the town in question and within the limits of available expertise, instruments or funding. Geomagnetic survey has often been used as the basic and prominent approach on urban Roman sites because of its relative speed and efficiency where few obstacles to the survey are present. Because of the two-dimensional nature of magnetic datasets, interpretations are usually limited and remain mainly qualitative. Archaeological interpretations of geophysical datasets preferably go beyond the mere identification of an anomaly as either pertaining to some archaeological feature or not: whenever possible, they will attempt to define the subsurface structure which caused the anomaly. Such interpretation is normally based on comparison with information available from other sites (Aspinall, Gaffney and Schmidt 2008: 143) but can also be greatly improved if further techniques are applied over the same area, such as electrical resistivity or ground penetrating radar, the two other most popular survey methods used in archaeology at present. The basic assumption informing the strategy of the Radio-Past project at *Ammaia* was that site-specific geophysical data integration procedure would enhance the overall archaeological interpretation beyond the traditional interpretation of just fluxgate gradiometer survey data (Kvamme 2006b, 2007). Therefore, additional electric resistivity and ground penetrating radar data had to be collected and integrated both qualitatively and quantitatively through a set of geophysical data combination techniques within a Geographic Information System (GIS). A selection of techniques was tested and evaluated, ranging from integration of qualitative interpretations to complicated data fusion. The added value of advanced data combination methods is still largely unknown, in relation to complex datasets resulting from surveys on urban archaeological sites. Some data combination methods can be applied with little extra effort, as they are available in widely used computer applications such as CAD packages or photo editing software. Other, more complex methods are used as a standard tool in ‘more-remote’ sensing and available through most GIS software. The latter are only infrequently utilized for processing and visualizing archaeological geophysical survey data.

General research context

Geophysical prospection is generally applied for (better) locating and evaluating sites or buried structures rather than fully investigating them (Gaffney, Gater and Van Ovenden 2002). Most surveys of non-threatened urban Roman sites are however, carried out in the context of academic research so they should be expected to do precisely the latter. These research-driven surveys aim to clarify the town lay-out and increasingly map the ancient city as extensively as possible. This presents a logistical issue of balancing speed of survey with resolution of the data collected in order to permit the observation of buried features. Therefore, a correct balance has to be found between the selection of survey parameters to detect the expected archaeological structures, and to allow for the size of the survey area given the time and budget available (Hesse 1999). The resulting data plots are then conceived as proxy maps of the subsurface rather than merely visualisations of measurements with specific geophysical properties. Increased sampling rates and a more precise location of the data result not only in better visualisations but also permit accurate data combination and modeling of the buried archaeological features through their geophysical signature (Hounslow and Chroston 2002; Boscoby, Cawlay and Chroston 2004).

As magnetic survey results generally detect most types of archaeological features within Roman urban sites, other geophysical survey techniques were only seldom applied on a large scale, mainly because they are more time consuming and hence expensive. Feature detection through multiple parameters enhances interpretative validity (Neubauer and Eder-Hinterleitner 1997; Neubauer, Eder-Hinterleitner and Melichar 2002). In addition, recent developments, such as DGPS equipped multi-instrument platforms and towed arrays, allow relatively rapid collection of more extensive but also more intensive geophysical datasets.

Whereas data collection and processing have evolved in a quite spectacular way in recent years, data interpretation has not. Simple interpretation methodology through subjective delineation of cultural or natural anomalies and their archaeological interpretation through mental comparison with known examples cannot be done much faster (Schmidt 2001a: 23; Gaffney and Gater 2003). In addition, control and documentation of interpretation consistency is only rarely done (Gaffney *et al.* 2000). Through partially automated data classification and interpretation, the cost to benefit ration for an integrated multi-parameter survey might be justified (Piro, Mauriello and Cammarano 2000). The importance of GIS as a tool for interpreting prospection-, excavation- and other data to create archaeological models or guide future research has been emphasized (Doneus and Neubauer 1998; Neubauer 2004). However, far too often this platform is only used to create, archive and manage the geophysical data and analyses are limited to simple overlays of vectorized anomaly delineations. These software packages offer more analytical tools and could even redefine questions asked of the archaeological record (Benech 2007).

The *Ammaia* strategy and operations

The strategy for geophysical survey at *Ammaia* had to consider that the many stone building materials used in this town of Roman foundation were mainly of sedimentary or metamorphic rock and to a lesser extent of granite. Additionally a lot of fragmented shale was present at the surface and that some heavy disturbances like modern pipelines, power lines and field terracing were likely to affect the results, potentially masking archaeological anomalies. Also of importance was the fact that dense vegetation is present in some parts of the site (zones with olive trees, dispersed chestnuts,…) and that a major road traverses the central part of the town-site. However, the first tests confirmed what had already been experienced in similar contexts where magnetometer surveys in particular have proven successful in detecting structural remains composed of material of sedimentary origin (Benech 2007; Strutt 2007). Since the soil matrix is derived from magnetically enhanced archaeological deposits and colluvial sediments good results are possible (Schmidt 2009; Strutt 2009: 7). In addition, earlier excavation work had shown the burial depth of many archaeological remains to be approximately 0,25m and that the remains of walls and their foundations were especially well preserved at *Ammaia*, even if certain floors and street surfaces were intensively robbed in recent centuries.

The first real test of geophysical prospection at *Ammaia*, in May 2008 – after some rather unsuccessful trials with a magnetometer a few years earlier – was achieved with a ground penetrating radar (GPR) instrument (Verdonck, Taelman and Vermeulen 2008; Vermeulen and Taelman 2010). In the last decades GPR has become one of the most valuable methods for the non-invasive investigation of complex urban sites (Leckebusch and Sutterlin 2007; Goodman 2009; Neubauer *et al.* 2009; Linford *et al.* 2010). As the earlier evidence from excavations in the forum of *Ammaia* pointed to well preserved stone structures, GPR produced good results. The general location and northwest-southeast orientation of the forum, and some of its crucial structural elements such as parts of the northern portico, were known from partial excavations carried out between 1994 and 2002 (Mantas 2000; Pereira 2009) and from the presence of the core of the temple podium which is still extant. The complex results (see section II.5.c) were essentially interpreted on the basis of profiles and 5cm thick depth-slices.

The quality of the information obtained from this first GPR survey, uncovering 2/3 of the ancient forum, leading to substantial revision of earlier theories on the layout of the monumental center of *Ammaia*, promted the research team to develop a plan for more intensive and varied geophysical investigations, involving the use of other instruments and techniques. The heart of the Roman town, the forum and an adjacent bath complex, were not only perceived as the best location at which to try out the effectiveness of several geophysical techniques, but it was also considered highly suitable for a well-integrated geo-archaeological methodology. The reasons for this are: the importance of human interference on the natural topography (typical for Roman forum sites), the good preservation of the underground monumental structures and the availability of reliable information from excavation which could be further enhanced. Once the site of *Ammaia* was chosen by the Radio-Past team as a suitable field-lab (see above) the decision was taken to organize, from June 2009 onwards, new and more intensive geophysical prospections. Within the limits of funding, accessibility to the fields and available instruments or know how within the consortium of researchers, it was decided to do a full coverage survey of the intramural part of the city and to cover accessible parts of the *suburbium* of the town with fast moving magnetic survey techniques and equipment, to select areas in the intramural city for intensive electrical resistivity survey and finally to apply and intensify the GPR survey in parts of the town centre. The forum area and certain residential parts of the city where initial magnetic results had shown great potential would be particularly targeted for coverage by all three methods, creating a solid base for intensive data fusion and high quality interpretations.

For the forum area these surveys were finalized in November 2010. Firstly, it was possible to obtain complete coverage of the forum with GPR. Field data were acquired with the same instruments as the initial survey, but with the addition of multiple sensors and the use of a quad for traction allowed for higher efficiency and speed. Secondly, full coverage of the area was also achieved with geomagnetic and electrical resistivity survey, both of which proved very successful. The varying nature of the deposits across the forum site provided good contrast in the signatures of all readings, indicating the presence of standing and crumbled walls, preserved wall foundations, porticoes with column bases, open spaces, floors and earth filling. The results show clearly how regularly the Roman forum was constructed, its main architectural spaces, the size and dimensions of its constituent elements and at the same time something of its complex taphonomy and history (Vermeulen, Corsi and De Dapper 2012).

After completion of the whole intra-mural area of the town with magnetic survey the choice for additional electrical resistivity[1] and GPR surveys in sample areas outside the monumental sector was made by weighing the importance of several archaeological questions. The following were prioritized: Firstly, can we obtain maximum information about a few seemingly well preserved *insulae* in the town, with clear subdivision into the individual housing units? Secondly, what was the topographical organization of the intramural water distribution system? Thirdly, is it possible to obtain a full plan of the forum-baths and their adjoining rich *domus*? Finally, how far does the urban topography extend to the north and what is the exact position of the town wall along the northern and southern sides of the settlement? Most of these questions could be positively approached and brought to conclusion, even if some uncertainties regarding the town limits still remain unresolved (see chapter II.4). These additional electrical resistivity and GPR surveys in the town area were completed in July 2011 by a GPR survey of the national road that crosses the site. This was the only approach capable of revealing traces of more deeply buried structures along this corridor which could be added to the general plan.

The interpretations presented here have been elaborated by different researchers. The data integration and open discussion among the team members has brought to a better comprehension of many features and elements, but some discordances remain in certain details of the interpretation such as in the exact dimensions of certain features or anomalies. In this sense, our choice was to leave to each author the freedom to present the individual elaboration.

Mind the gap

The fact that our strategy implied a “total survey” of the intra-mural space made us also face the problems connected with possible “gaps” in our evidence. As it has been repeatedly argued (e.g. Powlesland 2006; Campana and Piro 2009), “absence” in archaeological survey, and specifically in geophysical prospection, can be ascribed to many factors, some of which are purely ephemeral or occasional, but not necessarily meaningless.

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[1] Most researchers engaged in the geophysical survey in *Ammaia* chose the definition of “earth resistance” or “RES” to define the measurement of the electrical resistivity properties of the matter, as the process can be described as “feeding electric current in the ground and taking resistance measures at particular points” (Scollar *et al.* 1990; Clark 1996). This denomination of the technique has replaced the more traditional one of “resistivity” survey. Still, it is our care to underline that “resistance” (R) indicates the resistance of soil to the passage of electric current, while electrical resistivity (or, simply, resistivity, σ) is a fundamental material property which quantifies how strongly a given material opposes the flow of electric current. For the sake of accuracy, we should point out that the measured physical property is voltage, and that resistance cannot be measured directly. Following Ohm's law, the resistance can be calculated by a given current and a measured voltage. When including the geometry of the electrode array, then the apparent resistivity can be calculated. To get the “true” resistivity an inversion (inverse modelling) of the underground distribution of the resistivity is needed.

In the geophysical survey interpretation at *Ammaia*, one central issue has been the definition of "empty" and "full" spaces, of open and built areas. When it was about the definition of the urban layout and dimensions of blocks and intercalated streets, the discussion was animated, as we all have a different perception of "absence" and "presence" in both the geophysical and archaeological records.

In every field of science, the use of the argumentum *ex silentio* has always proved unwise and misleading, and, therefore, we avoided drawing conclusions on the basis of the lack of evidence. In this sense, the macroscopic "absence" of buildings for spectacles in the intra-mural and extramural survey (the latter, obviously surveyed in a less systematic and extensive way) is, at this stage of research, not considered indicative of a "gap" in the social life of the town or of a weak adaptation to the "Roman way of life" by its inhabitants.

Ground truthing via small-scale excavation

To reveal something more of the complex taphonomy and site history there is of course a need for some stratigraphic information and fine geo-archaeological and topographical analysis. At this point in the chain of operations at *Ammaia*, a true integration of the geophysics data with old and new stratigraphic datasets was pursued. Valuable feedback of archaeological information from excavation enhances the qualitative archaeological and geophysical interpretations of the whole survey dataset and vice versa. As geophysical survey often precedes excavation, this feedback is often problematic (Boucher 1996), and for the first geophysical surveys in *Ammaia* this was undoubtedly the case. Therefore, it was chosen to develop a program of small excavation interventions (see chapters I.1 and I.2) which chronologically were undertaken in parallel to the on-going surface surveys. Additional geomorphologic and soil context data, recorded during these excavations, helped to interpret natural features within the geophysical datasets, and especially to understand the nature of the archaeological materials in the buried record. As such, the archaeological excavations on the sites of the forum and baths could also serve as a test-environment to assess the geophysical survey techniques which were being applied (Maillol, Ortega-Ramirez and Berard 2005; Vermeulen, Corsi and De Dapper 2012) and assumptions about geophysical properties of the soil matrices and archaeological features made at the start of the survey could be corrected (Ciminale and Gallo 2004).

II.5.B INTRAMURAL GEOMAGNETIC PROSPECTION

P. S. Johnson

Introduction

This section presents the results of geo-magnetic field-survey work undertaken in three periods between July 2009 and October 2010 within the expected limits of the Roman town of *Ammaia* (see chapter II.4). The principal aim of this particular survey was to map the full extent of sub-surface archaeological features within the archaeological park owned by the *Fundacão Cidade de Ammaia* and those neighbouring properties which could be definitively argued to fall within the probable intra-mural area of the site. As has been discussed elsewhere in this volume (chapters I.1-I.2), the work was undertaken as part of a larger series of survey initiatives at *Ammaia*. It is however the element of the survey which has made the greatest contribution for our understanding of the town plan.

Methods

The 2009 and 2010 surveys followed methodological precedents set during extensive experience surveying Roman urban sites in the Mediterranean region (Keay *et al.* 2000; Johnson, Keay and Millett 2004; Hay *et al.* 2010). This survey strategy employed gridded collection of data (in contrast to the extra-mural survey presented elsewhere in this volume: II.5.f) and necessitated the establishment of a 20m x 20m grid, at approximately 45° to the known alignments of archaeological features, across the whole of the area to be surveyed. The grid was established using a Nikon DTM520 total station and was georeferenced to fixed geodetic points located within the Portuguese National coordinate system. This survey-grid was interrupted by the line of the N459 road between Marvão and Portalegre and an offset of 10m in both the easting and northing of the grid-origin was introduced between the western and eastern parts of the site during the setting out of the initial grid (chapter II.2).

The geo-magnetic survey was carried out using Bartington Grad 601-2 dual-sensor fluxgate gradiometers. Readings were triggered automatically, allowing the survey to be conducted rapidly, as the areas surveyed were largely free from obstructions. Data were sampled at 0.25m intervals along zig-zag traverses spaced at 1m intervals, the dual-sensor configuration of the instruments producing a sample density of 0.25m by 0.5m as two sensor tracks were recorded for every traverse walked.

Data were logged in the internal memory of the instruments which enabled a full day of survey to be completed before downloading to a PC using v 316 of the Bartington Grad 601 download software. The data were saved as .xyz files and then imported to Geoplot 3.1v for reconstitution and processing. The results derived from this processed data have been collated and presented for this publication using a range of software packages including Adobe Illustrator CS4, AutoCAD 2010, and Geoplot 3.1v. Interpretative plans of the anomalies were produced in AutoCAD from georeferenced raster images exported from Geoplot and then imported, along with those images, to Adobe Illustrator for presentation. The final published images are based on the information from the survey and additional data collected as part of the ongoing related archaeological work at the site of *Ammaia*.

The survey covered an area of approximately 18 hectares in total, within the archaeological area of *Ammaia* and neighbouring properties (Fig 35). All of the areas accessible to survey were completely covered by the gradiometer surveys of 2009 and 2010 with the bulk of the work being carried out by a two-person team in the 2010 seasons. These areas included two relatively large open fields and a series of small terraces. Much of the site was also covered with small olive trees which presented obstacles to the survey. The terrace walls and overgrown hedges show as gaps in the survey, as does the line of the N359 road from Portalegre to Marvão which runs broadly north–south through the middle of the site. As a result of modern enclosure of the land for stock-control purposes and the erection of temporary structures, the survey was also constrained in some areas in proximity to metal buildings and fencing, however the effect of this can be considered as minimal in the context of the whole site. Within the area surveyed, the archaeological features present on the site exhibited a particularly clear response to the geomagnetic survey and buried features showed clearly against the geological background. The general background response on the site is fairly uniform, enabling the archaeological features to present clearly in most areas. In the course of this discussion of the results, negative magnetic features suggest structural remains as the river-worn stones and schist commonly used for building exhibit a lower magnetic signature

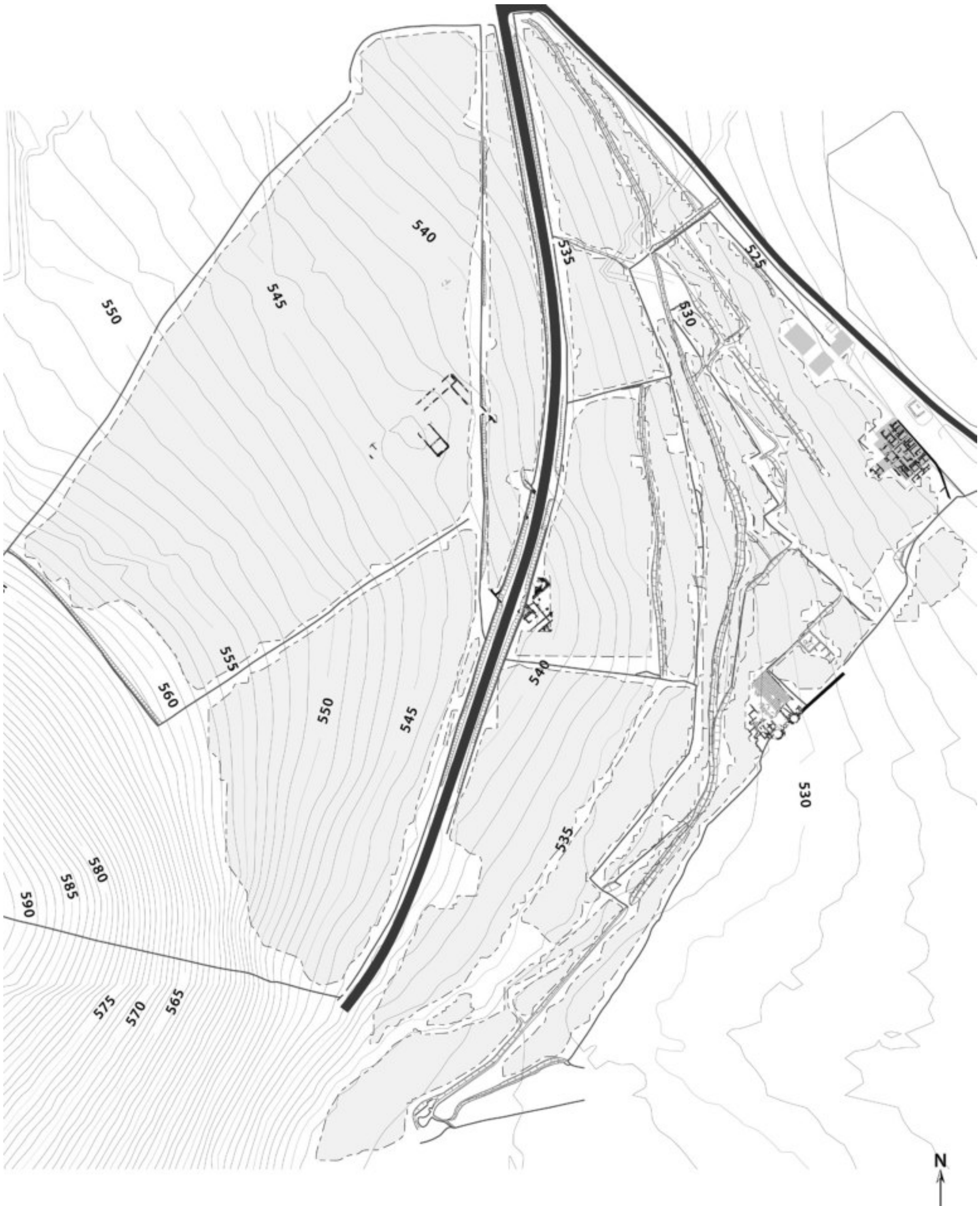

Fig. 35 Location of areas surveyed are shaded grey.

than the igneous geological background (as seen at a number of other Roman urban sites, see for example Bowden and Bescoby 2008; Heinzelmann, Jordan and Murer 2010: 63). Positive anomalies are generally interpreted as filled, stratigraphically-negative features such as ditches, or as areas of road-metalling. The dipolar anomalies present in the data fall into two broad categories, those with archaeological significance and those without. Features falling into the latter of these two categories will generally be discussed only where their identification requires explanation.

Magnetic gradiometer survey results

The results of the gradiometer survey are presented as a series of 1:2000 scale plans, located as shown on Fig. 36. A 1:3000-scale overall image of the gradiometer results is also provided for context and to enable the patterns visible across the data to be appreciated fully (Fig. 37).

The 1:2000 scale plans are provided as pairs, a greyscale plot of the gradiometer data being presented alongside a vectorised interpretative plan of the anomalies (Figs. 38-43). Throughout the discussion areas within the city will be

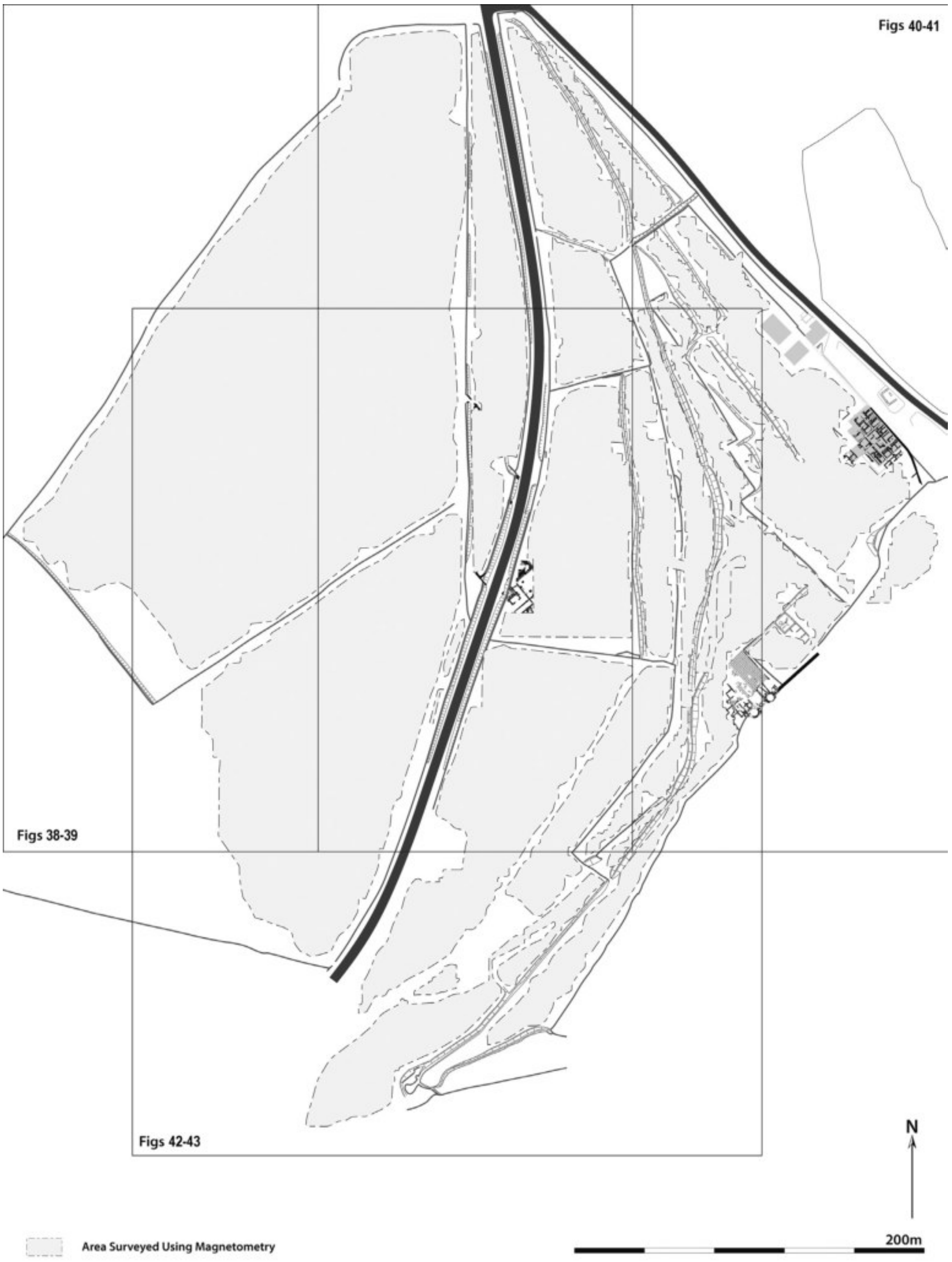

Fig. 36 Location of 1:2000 plans.

referred to on the basis of numbers assigned to an idealised scheme of building areas within the city, described as "blocks" to avoid the preconceptions associated with the use of the word "*insulae*", as part of our interpretation of the anomalies. These block numbers are allocated to building units which are separated by gaps or other features interpreted as the lines of ancient streets and should not be read as defining any particular form of ancient living-arrangement or structure. These streets will be referred to as *decumani* and *cardines* as a useful shorthand and to reduce confusion between northwest–southeast streets, the *cardines*; and southwest–northeast streets, the *decumani*[1]. The blocks have been defined on the basis of an appraisal of the overall plan of the geophysical anomalies and the following section discusses the archaeological identification and interpretation of these features. A table of concordances between the numbered blocks and the plans in which they appear is provided below (Table on p. 55).

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[1] For a more detailed discussion of the terminology here used to address urban streets, see Part III.

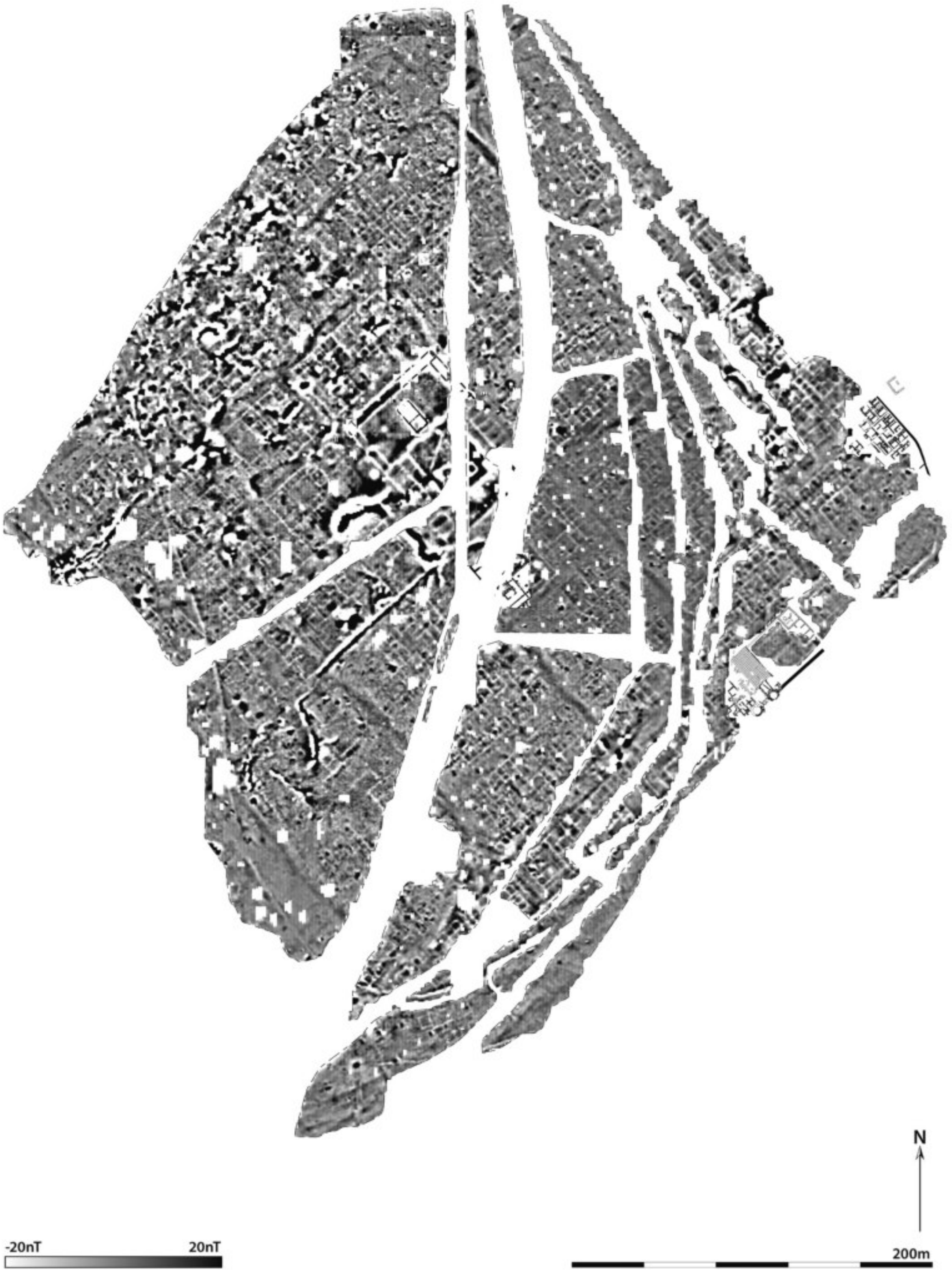

Fig. 37 Greyscale plot of the intramural geomagnetic survey data.

Blocks I, II & III

The area labelled as Block I (Figs. 38, 39) occupies a greater area than the majority of blocks defined within the town as a result of the lack of evidence for continuation of the *cardo* to the west of the forum area. This block is defined on its south-eastern edge by a feature [1], interpreted as part of the outer wall of a Roman structure running for 15.5m southwest–northeast. Further to the northeast is a small (*c.* 6m x 9m) structure [2], represented by negative magnetic anomalies, which apparently opens to the northeast onto a small piazza set back from the line of the second *decumanus* from the north of the site which it is possible to define through the geophysics. Whilst the anomalies representing this structure are restricted in their extent by the significant dipolar "noise" in this northern part of the site, it is likely that the visible structure represents just part of a larger building extending to the northwest within the area of the block. A short way to the northeast, but still fronting onto the *decumanus* to the south, is another structure [3], which

Insula Number	Present in Figs. 38/39	Prsent in Figs. 40/41	Present in Figs. 42/43
I	X		
II	X	X	
III	X	X	
IV	X		
V	X		X
VI	X		
VII	X	X	
VIII	X	X	
IX	X		X
X	X		X
XI	X	X	X
XII	X	X	
XIII	X	X	
XIV	X		X
XV	X		X
XVI	X	X	X
XVII	X	X	X
XVIII		X	
XIX	X		X
XX	X	X	X
XXI	X	X	X
XXII	X	X	X
XXIII		X	
XXIV	X		X
XXV	X	X	X
XXVI	X	X	X
XXVII		X	X
XXVIII		X	
XXIX	X	X	X
XXX	X	X	X
XXXI		X	X
XXXII		X	
XXXIII		X	
XXXIV			X
XXXV		X	X
XXXVI		X	X
XXXVII		X	
XXXVIII		X	
XXXIX			X
XL			X
XLI		X	X
XLII		X	
XLIII		X	

may well be part of the same complex as the previously discussed structure [2]. Immediately to the northeast of these structures is a range of buildings occupying the whole of the northeast face of block I and fronting onto the *cardo* [4], which appears to be the main axis of the site as it runs from the south gate, past the flank of the forum area and to the north of the city. The most likely interpretation for these structures would be as a series of *tabernae*, set into the outer edge of the block. To the north of this block is a positive anomaly [5] which strongly suggests the presence of the northernmost *decumanus* of the town.

The area labelled as Block II (Figs. 38, 39) exhibits significantly less interference from the dipolar “noise” characteristic of the area to the west and hence shows much clearer evidence for archaeological structures. The southern part of the block appears to be occupied by a *c.* 28.5m x 47m structure consisting of several rooms and open spaces [6], which appears to front onto the *decumanus* to the south. To the north is another complex structure [7], occupying c. 513m^2, apparently fronting onto the *cardo* to the north. This structure also includes what appears to be an apsidal space suggesting that it may not simply represent housing or *tabernae*, the nature of the evidence is not sufficiently conclusive to ascribe a definite interpretation to this feature but it may represent a later high-status *domus* or possibly have a function relating to bathing as apsidal rooms are common features of both these building types. This block is bounded on both of its long sides by *decumani* and there is evidence for the streets in the form of positive magnetic responses [8], which continues the line of [5] further to the northeast, and [9], which bounds both Block II and the eastern corner of Block I to their southeast.

Block III (Figs. 38, 39) is separated from Block II by the positive magnetic feature [10], which as with the previously discussed positive anomalies is highly likely to represent the metalling or paving of the Roman streets. Only a very few archaeological remains are visible in this block, being represented by a rectilinear, positive feature [11] occupying approximately 420m^2. The interpretation of this feature is unclear, it may represent the infilling of robber-trenches with thermoremanently or detritally magnetised sediment or material, or may represent a system of drains or other cut features associated with a structure or structures no longer present. To the east of this feature, aligned with [9] and appearing to define the extent of the *decumanus* to the south of Block III, is a positive magnetic feature flanked by two linear, negative features [12]. These are probably best interpreted as the edges of Blocks III and VIII and the surface of the street that divided them.

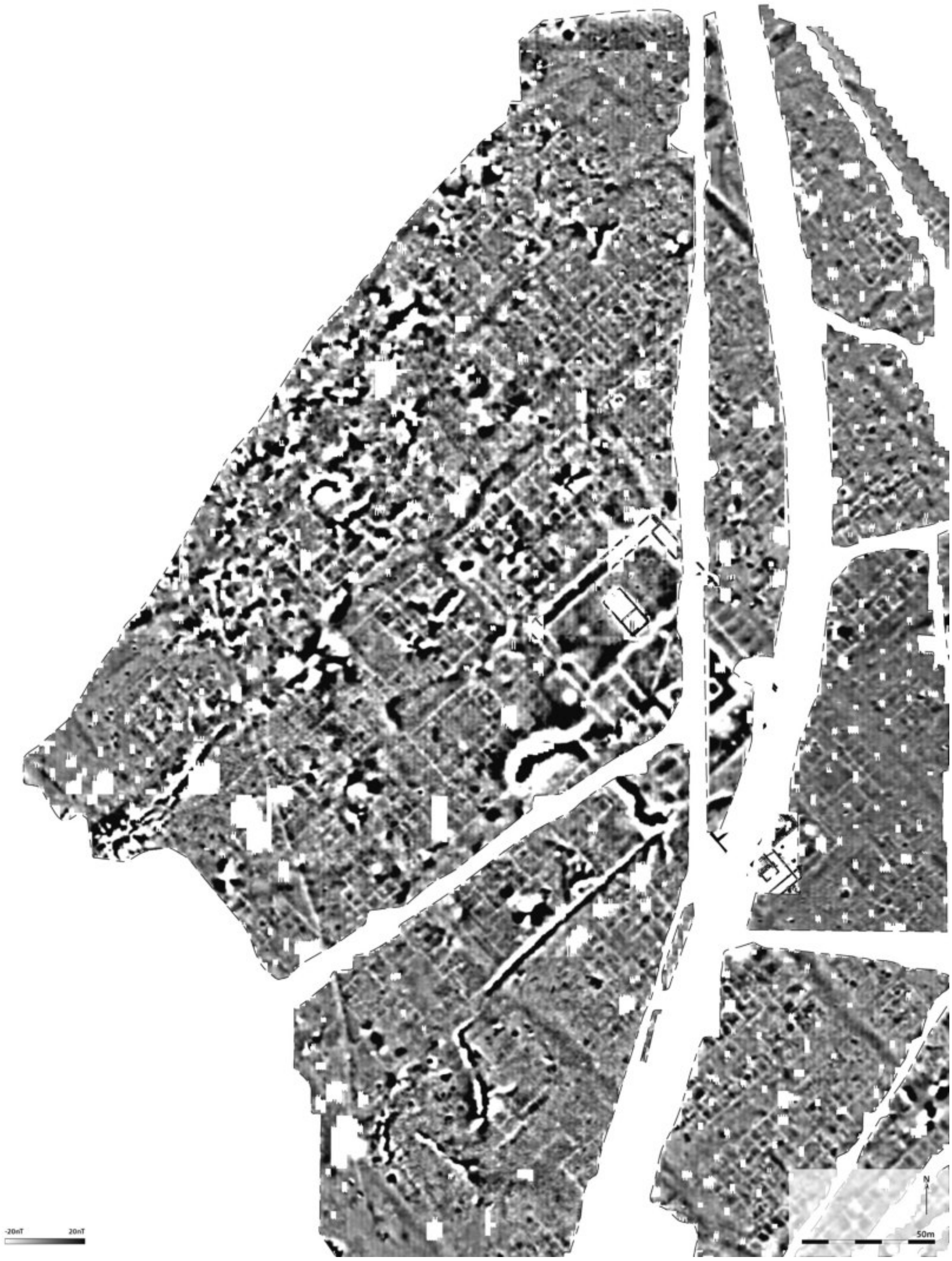

Fig. 38 Greyscale plot of the geomagnetic survey data from the northwestern part of the site.

Blocks IV, V, VI, VII & VIII

The area labelled as Block IV (Figs. 38, 39) occupies the westernmost corner of the site, at the point where the relatively gentle slope of the hill becomes steeper and impossible to survey. The western edge of Block IV is defined by a *c.* 13m long linear feature represented by a positive magnetic response [13]. As this feature is only *c.* 0.75m wide, it is unlikely to represent the surface of a street although its alignment does coincide with the westernmost *cardo* in the town to the south and may perhaps represent a roadside ditch or other drainage feature. The western part of this block appears to be virtually empty with the exception of a linear feature [14], represented by a positive magnetic response, and a series of small circular features, which appear to be associated with a more complex feature [15], associated with structures [16] covering the eastern part of the block. The interrelationship between [15] and [16]

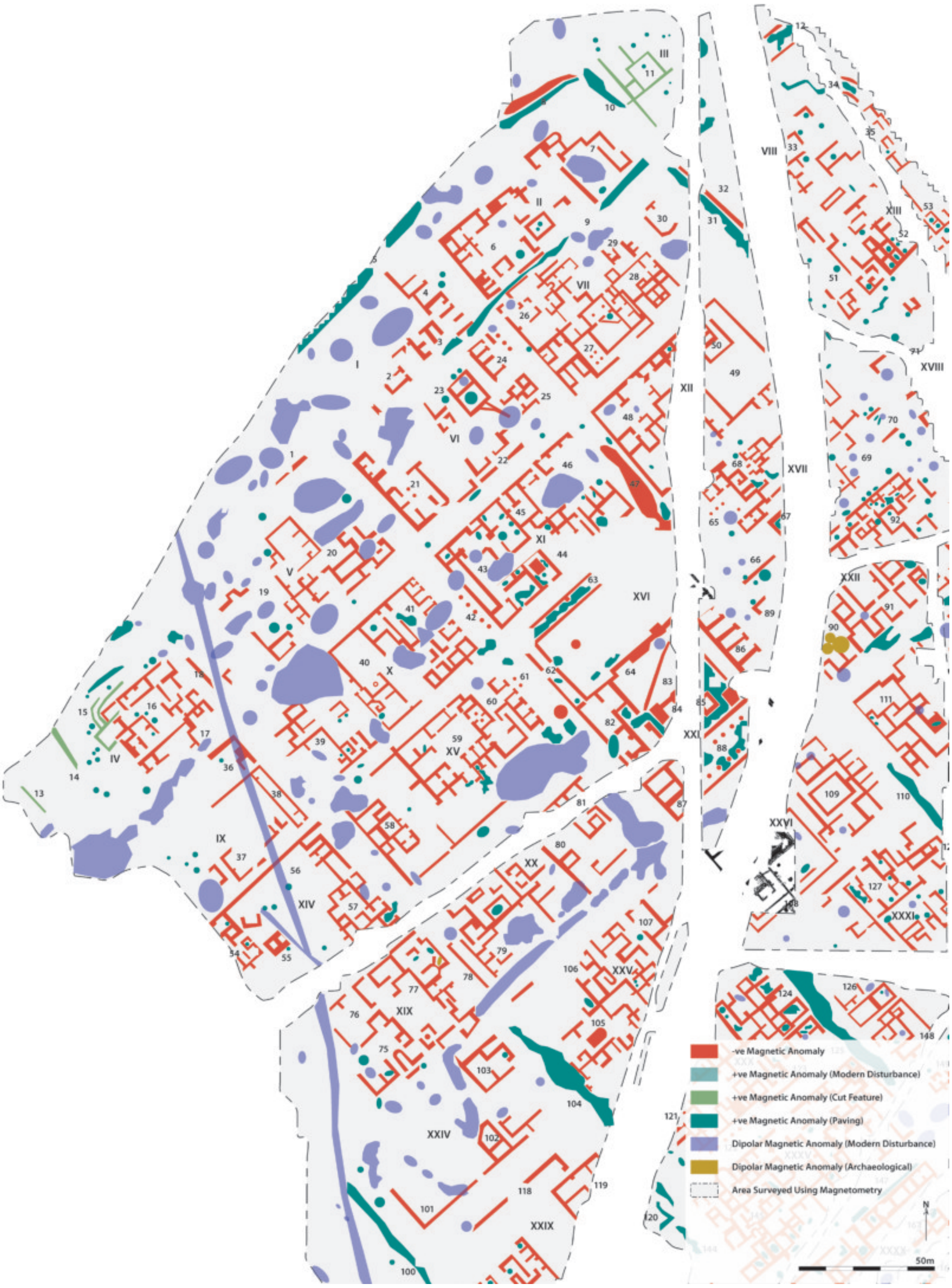
-ve Magnetic Anomaly
+ve Magnetic Anomaly (Modern Disturbance)
+ve Magnetic Anomaly (Cut Feature)
+ve Magnetic Anomaly (Paving)
Dipolar Magnetic Anomaly (Modern Disturbance)
Dipolar Magnetic Anomaly (Archaeological)
Area Surveyed Using Magnetometry
N
50m
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
XIII
XIV
XV
XVI
XVII
XVIII
XIX
XX
XXI
XXII
XXIV
XXV
XXVI
XXIX
XXXI

Fig. 39 Vectorised interpretative plan based on the geomagnetic survey data from the northwestern part of the site.

further supports the interpretation of [11] as cut features underlying or otherwise associated with structural remains which have not survived. Part of the structure defined by the negative magnetic responses [16] is an apparent later modification of the structure [17], which encroaches upon the *decumanus* to the south by at least 3.5m. Between this block and Block V is a structural feature [18], approximately 15m long, which is aligned along the *cardo* dividing the two blocks.

The geophysical responses in Block V (Figs. 38, 39) are relatively clear, however there is some interference from dipolar “noise”, particularly in the western part where the results are disrupted by the strong response from the line of a modern water-pipe. The central part of this block contains a series of responses [19] that resolve into structures for which it is not possible to ascribe any certain interpretation. The northern part of the block is heavily disrupted by dipolar “noise” but there is clear evidence for a substantial, 384m², structure [20], in the eastern corner of the block.

The survey results in Block VI (Figs. 38, 39) are also somewhat disrupted by dipolar "noise". The southern part of the block shows a number of negative responses [21] which represent a structure occupying an area of approximately 430m² which appears to show a series of rooms arranged around a colonnaded courtyard with no obvious openings to either the *cardo* to the west or *decumanus* to the south. The southwestern edge of the *insula* is defined by a range of structures [22], represented by linear, negative geophysical responses which appear to define an entrance at the centre of the block facing onto the *decumanus* to its south. The central part of the block is occupied by a *c.* 145m² structure [23], with a spur leading for 10m to the south of it. Whilst it is difficult to definitively provide an interpretation for this structure, its nature suggests that it has a hydraulic association and may relate to bathing or perhaps more likely to a garden feature such as a *compluvium* with associated run-off for a cistern, or a fountain. The northeastern edge of the block seems to be occupied by two distinct structures. The first of these two structures [24], almost certainly represents a series of *tabernae* fronting onto the *cardo* to the east and with evidence for a colonnade running along the side of the street. The latter of these [25], is a series of roughly square rooms which encroach upon the *cardo* to the east of the area and may therefore represent a later modification of the space.

Block VII (Figs. 38, 39) shows a much clearer response and more dense series of structures than those previously discussed. The whole of the western part of the block is completely covered by structures, in general these appear to be fairly undifferentiated in nature but appear not to have access onto the *cardo* to the west, rather the main access into the space seems to be from the *decumanus* to the south. Within this series of structures appears to be a large open space [26] in the western corner which also appears to include a small apsidal niche. Closer to the *decumanus* to the south are a pair of rooms or open spaces with evidence for columns either decorative or for supporting a roof [27]. Further to the northwest of this range of structures are a further series of small rooms [28], which appear to open onto an area in the eastern corner of the block which is obscured by dipolar "noise". Also obscured by this "noise" are a series of indistinct structures in the centre of the block [29]. At the northeastern edge of the area is a roughly rectangular structure [30], approximately 12.5m x 8m.

The area labelled as Block VIII (Figs. 6, 7) is separated from Block VII by an area with a low-positive magnetic response [31], which probably represents the surface of the *cardo* between these blocks and picks up the line of [10]. The western edge of the block itself is defined by a *c.* 36m long, linear, negative, structural feature [32] which is interrupted by a modern terrace. To the east are a series of structures [33], probably representing the internal divisions of a housing unit. It was however impossible to cover a sufficiently large area in this particular location to be able to make a more certain interpretation of the features seen. The northern corner of the block is unfortunately unclear, however there is evidence for a positive response, flanked by curvilinear negative responses [34], which may represent part of a street or filled structure. The eastern corner is occupied by structural features [35], which are unfortunately not sufficiently clear to form an interpretation of their ancient function.

Blocks IX, X, XI, XII & XIII

The area labelled as Block IX (Figs. 38, 39) is again located at the southwestern edge of the area surveyed, appears to be truncated by the slope and suffers from a great deal of dipolar "noise" which includes the line of the modern waterpipe also seen in Block V. The main archaeological features in this area are an L-shaped structure measuring *c.* 12.5m x 13m in the northern corner of the block [36], a range of structures which appear to front onto the *decumanus* to the south of the area [37], and another range of rooms [38], which appear to also open onto the *decumanus* but which run up the edge of the block along the *cardo* to the east.

Block X (Figs. 38, 39) also suffers from the effects of dipolar noise obscuring the archaeological features, however the results are still clear in the areas free from this interference. The southwestern part of the block consists of a series of structures which resolve into the plan of a building or series of buildings [39], with access to both the *cardo* to the west and *decumanus* to the south. Within this complex is what appears to be an open space in the centre of which is a rectangular structure of 5m x 5.5m and two positive responses which may indicate pits. The centre of the block consists of a large complex structure indicating a series of large rooms or open spaces [40], which may access the *decumanus* to the south but almost certainly had its main entrance in the centre of the side of the block facing the *cardo* to the east. Arranged along this side of the block and to either flank of the entrance to the central structure are a series of at least 5 small rooms [41], which must represent *tabernae* or small artisan workshops.

The area labelled as Block XI (Figs. 38, 39) has less of a problem with dipolar "noise" but it is still present over approximately 20 % of the area. The block is flanked to the southeast along the line of the *cardo* by an apparent colonnade [42]. The southwestern part of the block itself is dominated by a series of structures [43], which show no clear evidence of entrances to any side except the *decumanus* to the southeast. One part of these structures appears to be a

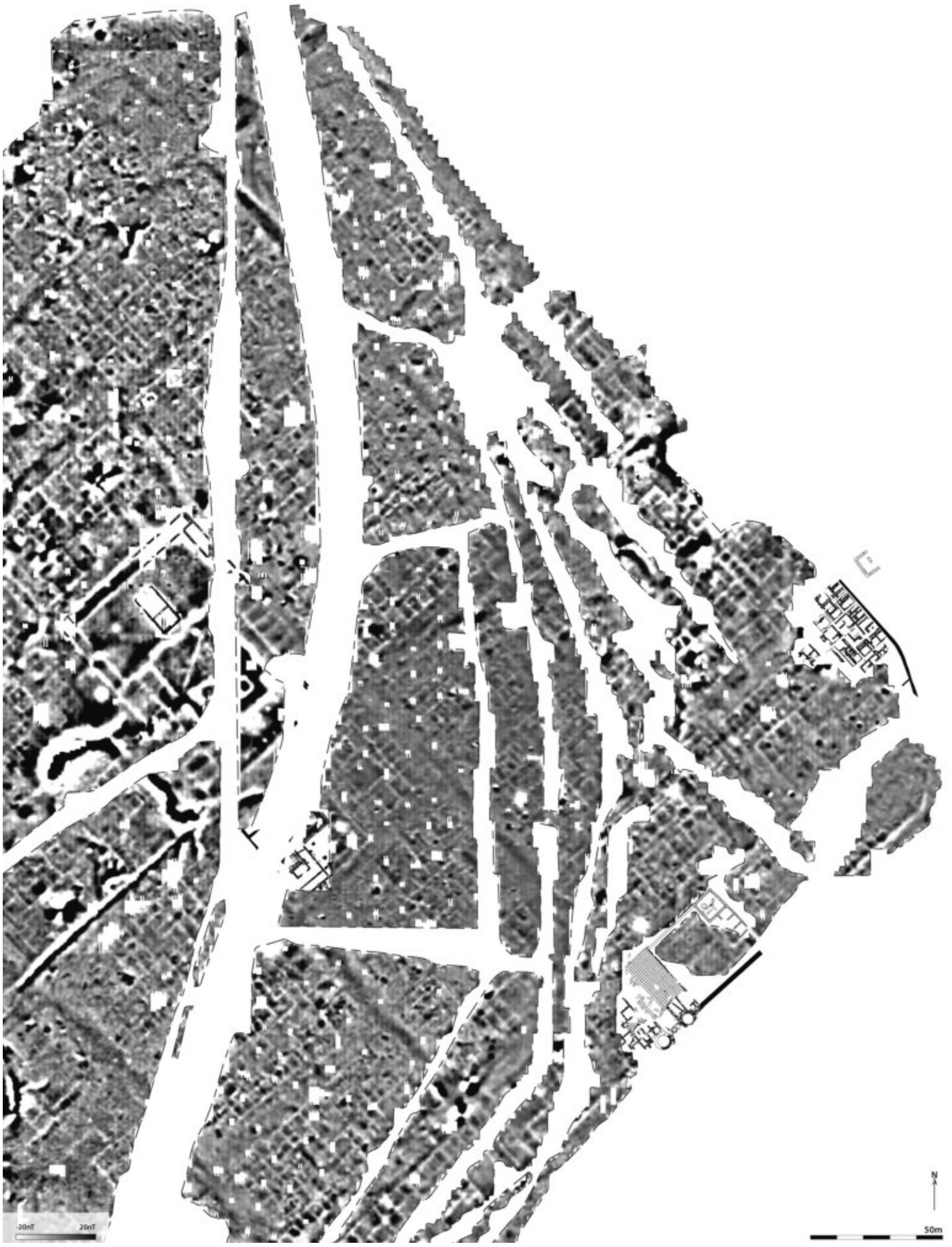

Fig. 40 Greyscale plot of the geomagnetic survey data from the northeastern part of the site.

room with one entrance onto the *decumanus*, which exhibits geophysical responses suggestive of flooring and a solid rectangular structure measuring *c.* 4m x 5m in its centre. The centre of this southeastern side of the block is characterised by a large open area [44] which probably gave access onto a number of rooms both within the previously discussed complex [43], and immediately to the north and northeast. Located in the middle of the northwestern side of the block are negative anomalies [45], which are interpreted as a pair of rooms (one within the other) accessing the *decumanus* to the northwest. The northern corner of the area exhibits responses which suggest a structure [46], accessed from the street to the northwest, but with an internal structure where the individual rooms appear to have faced inwards to a courtyard or other open space within the building.

Block XII (Figs. 40, 41) is separated from Block XI by the line of the main *cardo*, running from the south gate to the northern edge of the town. The line of the road is represented by a low-positive magnetic response [47]. The block itself is heavily interrupted by modern terracing and the line of the modern N359 road. The main structural features visible are what is interpreted as probably a large, fairly high-status dwelling on the basis of the size of the rooms, to

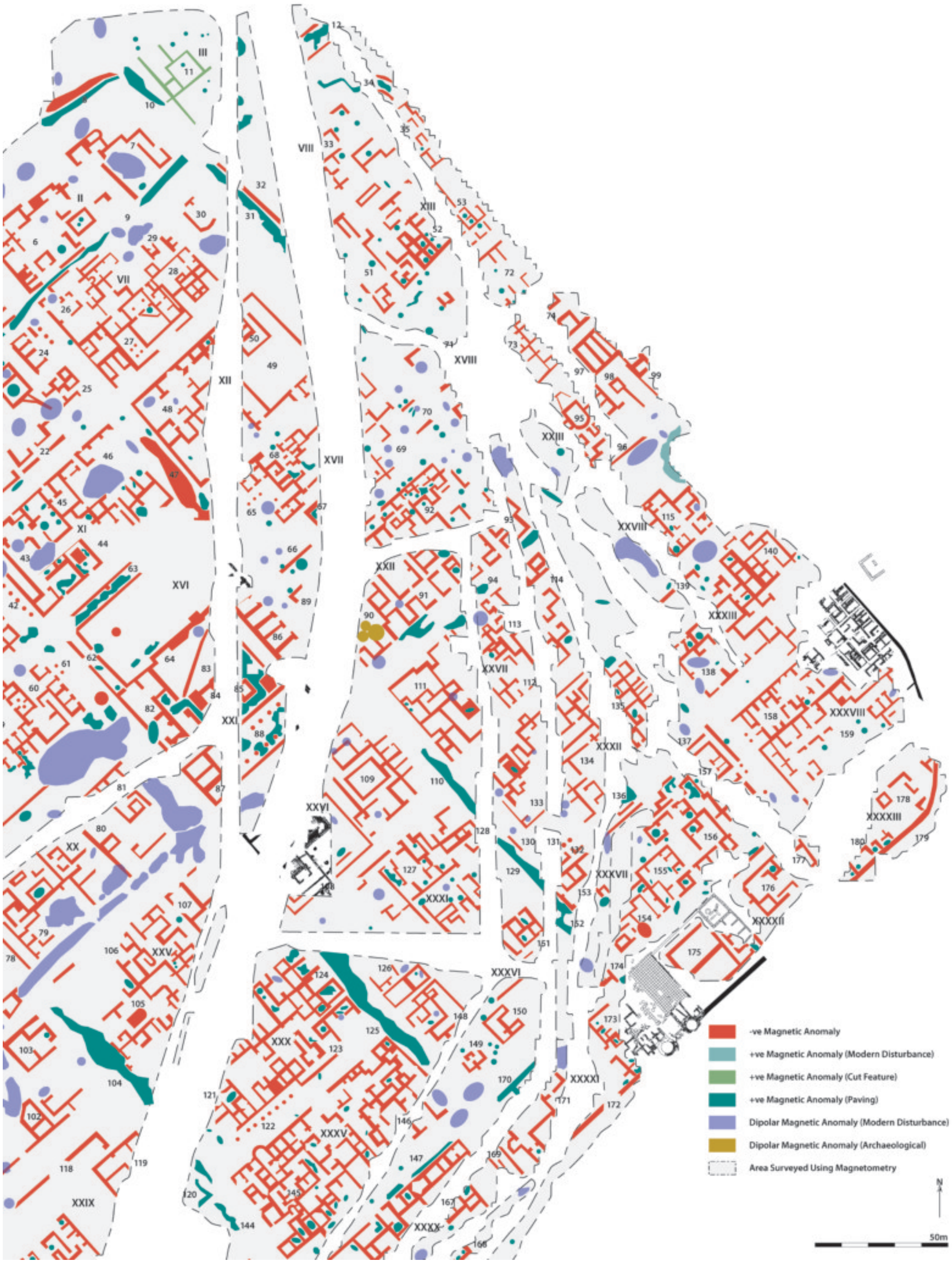
-ve Magnetic Anomaly
+ve Magnetic Anomaly (Modern Disturbance)
+ve Magnetic Anomaly (Cut Feature)
+ve Magnetic Anomaly (Paving)
Dipolar Magnetic Anomaly (Modern Disturbance)
Dipolar Magnetic Anomaly (Archaeological)
Area Surveyed Using Magnetometry
N
50m
II
III
VII
VIII
XI
XII
XIII
XVI
XVII
XVIII
XX
XXI
XXII
XXIII
XXV
XXVI
XXVII
XXVIII
XXIX
XXX
XXXI
XXXII
XXXIII
XXXV
XXXVI
XXXVII
XXXVIII
XXXX
XXXXI
XXXXII
XXXXIII

Fig. 41 Vectorised interpretative plan based on the geomagnetic survey data from the northeastern part of the site.

the west of the terrace [48]. To the east of the terrace and west of the N359 are a series of linear, negative responses which appear to delimit a large, broadly rectangular, open space of approximately 830m² [49], which has an apparent access onto the *decumanus* to the southeast. Within this open space are a group of rectilinear, negative responses [50], which appear to define a substantial structure of at least 12m x 12m located centrally at the northwestern end of the area.

The area defined as Block XIII (Figs. 40, 41) is located at the eastern edge of the site. The features in this area are fairly clear, however there is some interruption from modern terracing and overgrowth where it was impossible to survey. The southwestern part of the area exhibits few features which can be confidently interpreted as anything but structures of some sort [51]. The central part of the block is slightly better with a series of clear structural responses [52], some of which also show positive responses, probably from infilling of the rooms in antiquity, within them. The northeastern sector also exhibits similar features as the central section [53], though as a result of the modern topographical restrictions these are fewer and more difficult to interpret.

Blocks XIV & XV

The area labelled as Block XIV (Figs. 38, 39) is once again located at the western edge of the area which it was possible to survey and is also interrupted by the line of the modern water-pipe, although in general there is less dipolar "noise" in this area. The archaeological anomalies consist of a series of structural responses along the western edge [54], which may access a possible *cardo* to the west and also, more certainly an open area in the centre of the block to the northeast. Adjacent to this, also to the west of the modern pipeline, is a substantial rectangular, negative response [55]. The interpretation of this latter feature is unclear but it is suggestive of a monumental structure, as a result of the strength of response the structure must be more substantial than those representing walls being interpreted as housing or other buildings. The northeastern part of the block is bounded by negative responses interpreted as a boundary wall and small rooms [56], facing onto an open space within the block and also out onto the *cardo* to the northeast. The eastern corner is occupied by a complex of structural anomalies [57], which suggest a series of rooms based around a large central room or open court.

Block XV (Figs. 38, 39) has more interference from "noise" than the previously discussed one, including a large "fish-shaped" anomaly in its eastern corner. The southwestern edge of the block is dominated by a series of structural anomalies [58], which define a number of rooms with no apparent access to the street. The majority of the area is occupied by a series of anomalies [59], which define a substantial structure which is interpreted as rooms opening onto a central courtyard with possible access to the *decumanus* at the northwestern corner of the block and also into what is probably another, larger open space to the southeast, within the area of the block. The northeastern edge of the block is defined by negative responses [60], which suggest a series of *tabernae* opening onto the *cardo* to the northeast. The southwestern edge of this *cardo* appears to have been colonnaded, as is suggested by the presence of circular, negative responses [61].

Blocks XVI & XXI

The following two blocks are considered together as they form a contiguous area which is interpreted as the central forum of the city (Figs. 38, 39), widely discussed also in section II.5.e of this book. Block XXI and the numbered features within it are therefore out of sequence with the rest of the features discussed. Although these two blocks are clearly integrated and there is no evidence for a *decumanus* separating them, there is a distinction between the areas labelled as Blocks XVI and XXI in the form of the anomalies present within them. Block XVI contains the extant remains of a temple podium and several excavated "Wheeler squares" which have exposed the remains of a portico or a *cryptoporticus* on the western side of the complex (Vermeulen, Corsi and De Dapper 2012: 134-136), bounding the sides of the platform on which the temple is situated. The geophysical responses [62] and [63] represent continuations of this *cryptoporticus* and the infilling of it with debris and sediment as can be seen in excavated sections (Vermeulen, Corsi and De Dapper 2012: 136). The linear, negative magnetic response of feature [64] was thought to represent the edge of the platform upon which the temple was situated, but recent ground-truthing excavations seem to disprove this reconstruction (Vermeulen, Corsi and De Dapper 2012: 132-133). The remaining area, labelled as Block XXI, represents the larger part of the forum. In the centre of the southwest side of this area are a series of negative responses [82], indicating rooms and structures which appear not to demonstrate access onto the *cardo* to the southwest although this may be a result of archaeological preservation rather than an accurate representation of the situation in antiquity. In the centre of the open space is a linear, negative response [83], running for *c.* 27m between the edge of the platform and a large, substantial feature [84], to the south of the open space. The eastern corner of the forum appears to be occupied by a square structure *c.* 6.5m x 6.5m, surrounded by an area of positive response which may well signify the presence of intact paving [85]. The northeastern side of the forum is occupied by a series of structural responses which can confidently be interpreted as *tabernae* fronting onto the *cardo* to the northeast [86], it should be noted that these *tabernae* and the road would have been at a significantly lower level than the forum square and podium of the temple. The southeastern side of Block XXI is occupied by a series of substantial structural responses which correlate with extant masonry in the field and edges of the cutting for the N359. These broadly resolve into two parts of the same structure, the first are three large rooms or spaces [87], which could possibly be related to the activities which took place in the basilica (a sort of *aedes Augusti*? see section III.1.a). The remaining structural responses are much easier to interpret as two parallel walls running for approximately 22m southwest–northeast alongside the line of the *decumanus* to the southeast, two parallel series of columns within the area defined with the walls and positive responses which probably indicate a floor [88]. The combination of these features and their location is strongly suggestive that this would have been the basilica of the Roman city.

Blocks XVII & XVIII

The area labelled as Block XVII (Figs. 40, 41) has the N359 running through the middle of it and as a result the archaeological responses are not as clear they might otherwise have been. The southwestern side of the block appears to be largely devoid of structural responses, an open courtyard or square [65], with some evidence for a colonnade, opens towards the *cardo* to the southwest. Around this courtyard are arranged what appear to be a series of rooms. At the southern corner of the area there is a linear, negative response [66], which runs for approximately 15m along the line of the *decumanus* to the southeast. Approximately 7m to the northeast is a truncated rectilinear feature consisting of a negative response which bounds an area of positive magnetic signal [67]. The truncation of this feature by the line of the modern road is problematic for interpretation but it must represent a building or structural feature, either paved or infilled with sediment. The majority of the area to the west of the N359 is occupied by a series of complex structural features [68], which appear to front onto the *decumanus* to the northwest. The relatively small area (c. 600m^2) to the east of road N359 exhibits a number of structural features [69], which are unfortunately too fragmented for any meaningful interpretation to be made. There is some debatable evidence for encroachment onto the *cardo* to the northeast with two, parallel, 6.5m long negative responses [70], perpendicular to the line of the street and cutting across it.

The area of Block XVIII (Figs. 40, 41) is once again limited by the presence of areas which were impossible to survey. A series of structural responses line the western sides of the area [71], confirming the lines of the *cardo* to the southwest and *decumanus* to the northwest. The northern corner of the area demonstrates only a few structural anomalies [72], these do however confirm the continuation of the *decumanus* to the north and that structures were present this far to the east, even if the nature of those structures is unclear. In the centre of the southeastern flank of the block is a negative response [73], which can be interpreted as a series of rooms facing northeast and southwest, arranged along a central spine, perpendicular to the *decumanus* to the south and blocking it. To the east, the only remaining responses in this area are more substantial, negative features [74], which again appear to represent buildings of some form.

Blocks XIX & XX

Block XIX (Figs. 38, 39), is located at the western edge of the area surveyed and as with previously discussed areas along this side of the site, is interrupted by the line of the modern water pipeline. The features in this area are fairly clear with evidence for structures arranged around courtyards or other open spaces in the southwestern part of the area [75] and [76]. The northeastern end of the block is occupied by a series of negative responses which are interpreted as a suite of rooms [77], probably fronting onto the *cardo* to the northeast and which also encroach upon the *decumanus* to the southeast. Within this suite is a room which appears to have an apsidal northeastern end, whilst a specific interpretation is problematic, the proximity of a small dipolar feature on the other side of the wall might suggest the room was heated as part of a private bath or possibly that the room served as a *triclinium* with floor heating or an oven/hearth as part of the process of food preparation. This block is separated from Block XX by the proposed line of a *cardo*. The linear, negative response [78], which runs more-or-less along the middle of this street, suggests that the buildings of either Block XIX or XX encroached onto the cardo at some point, or that a sewer system is located here.

The area labelled as Block XX (Figs. 38, 39) exhibits a greater concentration of magnetic responses including a curious, linear, dipolar feature (not numbered), which is coincident with the intersection between the edge of the structures and the line of the *decumanus* to the southeast. A number of hypotheses have been proposed for the interpretation of this feature including its being part of the system supplying water to the town in antiquity. The nature of the geophysical responses is, however, not consistent with either a stone or lead-lined channel or pipe and the anomaly is more likely to result from relatively modern drainage schemes or cabling. The archaeological features within the block broadly define two areas. To the southwest are a series of negative responses [79], indicating structures which are probably arranged around a central courtyard. To the northeast however there appears to be a *c.* 25m long linear feature [80], interpreted as a structure which divided the two parts of the block from each other. The northeastern end of the block is also occupied by structural features [81], which are unfortunately too few and indistinct for a confident interpretation of their nature to be ascribed.

Blocks XXII & XXIII

The area of Block XXII (Figs. 40, 41) is heavily truncated towards its western end as the N359 passes through it. However, apart from this one major interruption, the results visible are fairly clear. The western corner of the block is defined by a *c.* 6m x 4m “L-shaped”, negative response, structural feature [89]. This feature is the only one located to the west of the N359 and is presumably heavily truncated by it. To the east of the modern road is a complex series of structures [90], containing a group of three dipolar anomalies which might be archaeologically significant. Slightly further to the east these structures continue with what appears to be an access onto the *decumanus* to the southeast and to a courtyard area within the block [91]. The northern part appears to be occupied by a more-dense concentration of smaller rooms [92], these show no evidence of access to the *decumanus* running along the northwestern side of the block and so presumably would have had their entrance on the *cardo* to the northeast. The final group of structural responses appear to demonstrate the encroachment of buildings in this area onto the northeastern *cardo* and southeastern *decumanus* at the eastern corner of the block [93]. The encroachment onto the line of the *cardo* is particularly pronounced with approximately 60% (or 10m) of its width taken up with the building. The line of the southeastern *decumanus* can be inferred from the presence of positive responses to the southeast of the block [94].

Although it was possible to survey the majority of the area labelled as Block XXIII (Figs. 40, 41), the modern terracing rendered the individual areas covered in the western part too small for any significant features to be discerned. The central part of the block appears to show a number of negative responses [95], which suggest the presence of buildings an element of which appears to be a structure with a curved southeastern end. This structure also seems to be associated with less substantial, angled responses to its northwest which suggest that it may relate to a "water-feature", whether a cistern, pool, nymphaeum or fountain is however unclear. The southeastern edge of the block is defined by a *c.* 17.5m long, linear, negative response [96], which confirms the line of the *decumanus* to the southeast. The substantial negative responses to the north of the block suggest the presence of a structure [97], however its morphology does not lend itself easily to interpretation. In the centre of the eastern end of the block is a square feature [98], with a trailing linear response to the southeast, suggesting that this may also represent some form of water feature. At the very northeastern edge of the block is a group of negative responses [99], which probably represent the wall of the city and adjacent/abutting structures.

Blocks XXIV, XXV, XXVI, XXVII & XXVIII

Block XXIV (Figs. 42, 43) is located at the western side of the postulated intramural town area, its southwestern edge is defined by the probable line of a *cardo* indicated by the presence of an area of positive response [100]. This block is partially obscured by dipolar "noise" and the responses are also partially muted, probably as a result of increased deposition overlaying the archaeological remains. An "L-shaped" linear negative feature [101], measuring *c.* 19m x 27m defines the southern corner of the block. Further to the northeast, along the southeastern side of the block is a group of structural anomalies [102], of which it is not possible to make any certain interpretation of their form. The northern corner of the block is occupied by *c.* 330m^2 of structural responses [103], which appear to front onto the *cardo* to the northeast. This block is separated from Block XXV by an area of positive magnetic response [104], which confirms the line of the *cardo*.

Block XXV (Figs. 8, 9) itself shows a fairly dense series of structures but is truncated to the east by the line of the N359. The southern part of this area shows anomalies [105], which are interpreted as a series of rooms fronting onto the *decumanus* to the southeast, opening onto a large open space set back from the street, with a large, solid structure in its centre. The centre of the block is occupied by a complex series of structural responses [106], these appear to front onto the *decumanus* to the northwest although their internal arrangement is not entirely clear. The northern part of the block demonstrates a further series of structures [107], which do not appear to connect with the structures in its centre.

Approximately 50 % of Block XXVI (Figs. 42, 43) is occupied by an excavated bath complex. The lines of the walls of this bath complex, in the southern corner of the block, are continued by linear, negative responses [108], which encroach onto the *cardo* to the southwest and *decumanus* to the southeast. The northern part of the block is occupied by a series of structures [109], fronting onto the southeastern *decumanus* and *cardo* to the northeast, defining a large central space within the block. This block is divided from Block XXVII by an area of positive magnetic response [110] which confirms the alignment of the *cardo*.

The area labelled as Block XXVII (Figs. 40, 41) can be divided into broadly three zones. In the southern part of the block is a group of structural anomalies [111], which appear to show limited access to the *cardo* to the southwest and mainly front onto the *decumanus* to the southeast. Approximately half way along the southeastern flank of the block are a series of small structural features [112], which appear to represent *tabernae*. To the north of these a group of structural responses [113], appear to define a series of small rooms in the centre of the area and possibly more *tabernae* opening onto the *decumanus* to the northwest. The northeastern part of the block is occupied by further structural anomalies [114], which also exhibit evidence of encroachment onto the *cardo* to the northeast.

The only structural features present in Block XXVIII (Figs. 40, 41) occupy the centre of the southeastern flank of the area. These responses [115], suggest a series of rooms opening onto the *decumanus* to the southeast and a probable internal courtyard.

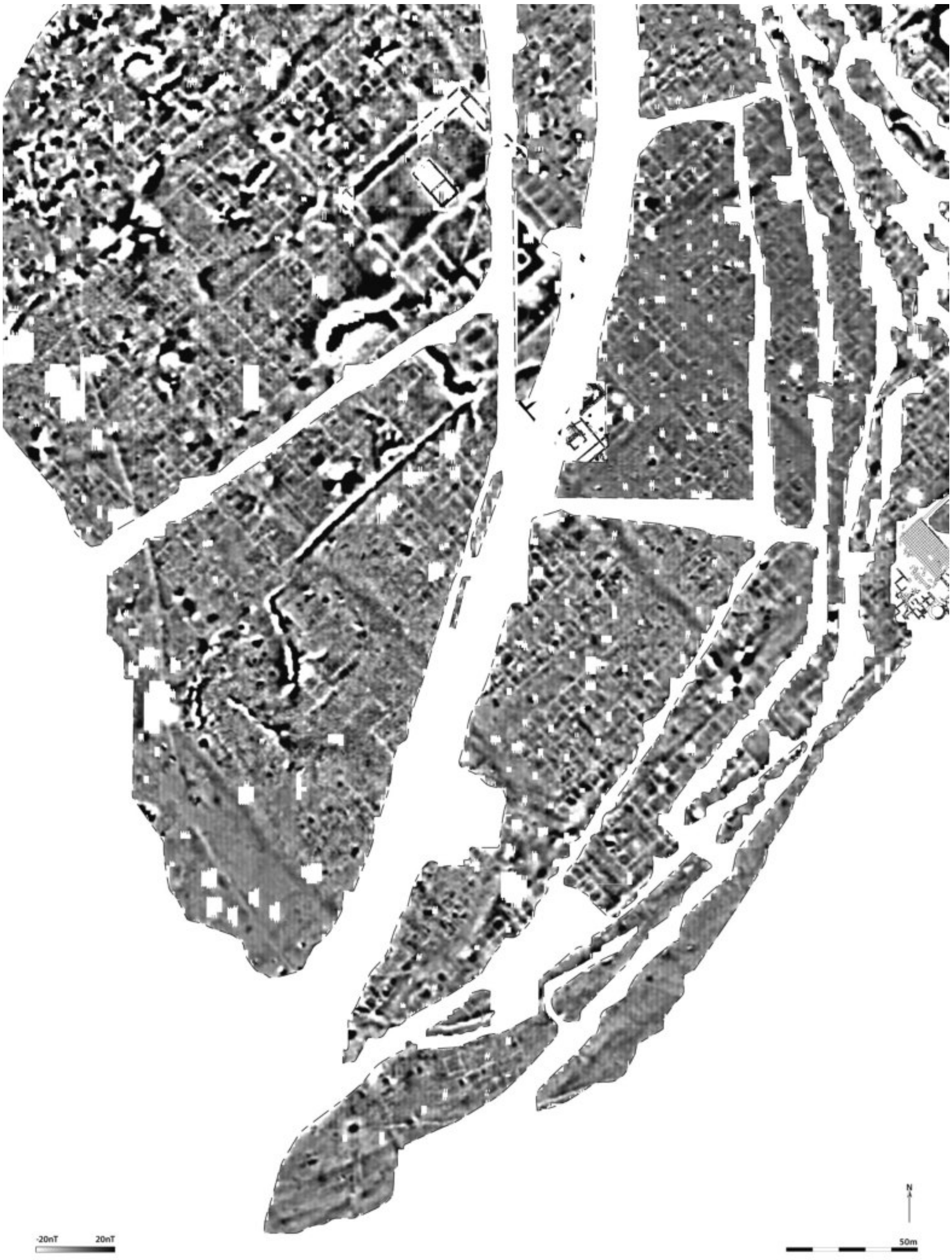

Fig. 42 Greyscale plot of the geomagnetic survey data from the southern part of the site.

Blocks XXIX, XXX, XXXI, XXXII & XXXIII

At the southern corner of Block XXIX (Figs. 42, 43) are a pair of positive magnetic responses [116], which probably define the line of the *decumanus* to the south of the area running to the southwest. The southern corner of the block is occupied by a series of fairly nondescript structural features [117], which abut the lines of the *cardo* to the southwest and southeast of the block. The centre of the area is apparently devoid of archaeological features with a c. 42m long linear, negative response [118] defining the northwestern edge of the structures within the block. To the east of this, truncated by the line of the N359, is a group of structural features [119]. The eastern corner of the block appears to be defined by positive responses [120], which define the corner of the *cardo* to the northeast and *decumanus* to the southeast.

The area labelled as Block XXX (Figs. 42, 43) is truncated to the west by the line of the N359. The southeastern flank

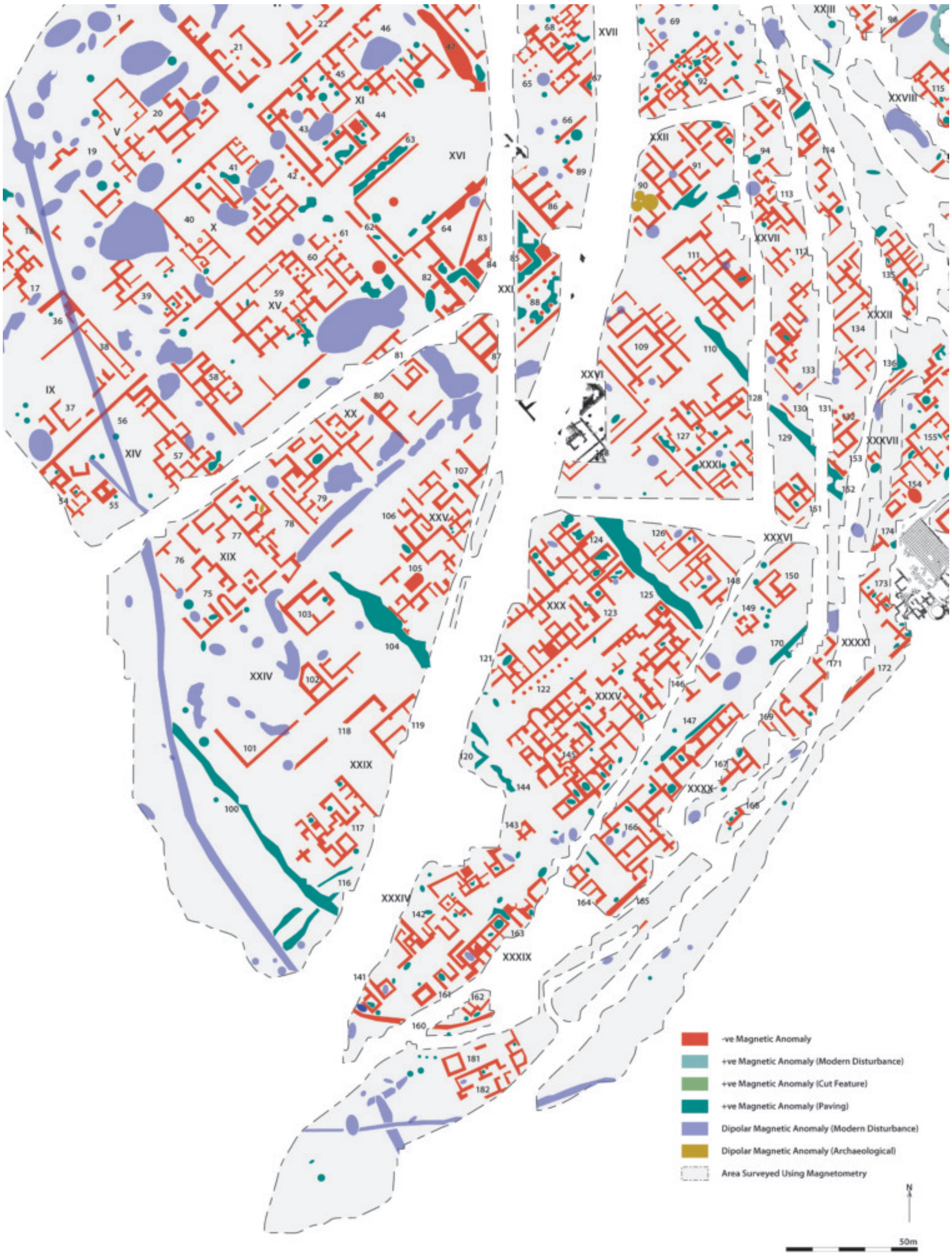
-ve Magnetic Anomaly
+ve Magnetic Anomaly (Modern Disturbance)
+ve Magnetic Anomaly (Cut Feature)
+ve Magnetic Anomaly (Paving)
Dipolar Magnetic Anomaly (Modern Disturbance)
Dipolar Magnetic Anomaly (Archaeological)
Area Surveyed Using Magnetometry
N
50m

Fig. 43 Vectorised interpretative plan based on the geomagnetic survey data from the southern part of the site.

of the block appears to consist of a group of structures [121], which are likely to relate to the *decumanus* but do not show any obvious signs of doorways. This interpretation is reinforced by the presence of a series of features [122], which are interpreted as representing a colonnade running along the northwestern side of the street. Along the same alignment but seemingly not interconnecting with these structures are a further series of rooms [123], which occupy the eastern corner of the *insula*. The northern part of the area is defined by a series of structural responses [124], which appear to access both the *cardo* to the northeast and *decumanus* to the northwest. This block is separated from Block XXXI by an area of positive magnetic response [125], which defines the line of the *cardo*.

The area of Block XXXI (Figs. 42, 43) is broken up by modern field boundaries and terraces. The southern corner of the block is occupied by structural responses [126], which appear to define a large (c. 7m x 18m) building at the corner itself and some associated structures. The central part of the block exhibits a complex of structural responses [127], from which it is not possible to draw any definitive interpretations. These structures also appear to show some evidence of modification or encroachment over the line of the *cardo* to the northeast [128]. The latter as defined by the previously discussed response [110], is picked up by a similar feature [129].

The area defined as Block XXXII (Figs. 40, 41), is also fragmented by modern terracing and field boundaries. The edge of the block along the *cardo* to the southwest is defined by a short negative-response feature [130]. There is also evidence for a colonnade along the edge of the *decumanus* to the southeast [131], as well as for the encroachment of buildings into the street [132]. The centre of the southern part of the area is occupied by a series of structural responses which define a number of rooms and possibly an open courtyard [133]. The central section of the block is similarly occupied by structural responses [134], clearly indicating a densely occupied urban environment but providing insufficient detail for a more certain interpretation. The northeastern part of the block exhibits structural responses [135], characteristic of *tabernae* fronting onto the *cardo* to the northeast of the block, with additional rooms to their rear. The line of the *decumanus* to the southeast is defined by a positive response and also a linear, negative response [136], which is more likely to represent a structure associated with the street rather than encroachment of the buildings to the northwest. There is a linear negative feature [137], at the eastern corner of this block which may represent a continuation of the previously discussed feature.

Block XXXIII (Figs. 40, 41) shows clear evidence of structures although it is truncated by the corner of the archaeological museum to the east. The southwestern edge of the block exhibits a group of structural responses [138], the detailed interpretation of these features is unclear. The northwestern edge of the area is defined by *c.* 18m long linear structural responses [139]. The remainder of the structural responses in the block can be resolved as a complex of buildings with fairly small rooms [140]. Whilst the interpretation of these features is not certain, they are likely to represent fairly low-status dwellings or workshops.

Blocks XXXIV, XXXV, XXXVI, XXXVII & XXXVIII

The responses in Block XXXIV (Figs. 42, 43) are severely truncated by the line of the N359 and only the southeastern part exhibits archaeological features. The southern corner of the block exhibits an interesting mirrored pair of structural responses [141]. Whilst their interpretation is uncertain, they may have an association with the line of the city wall which probably lies less than a metre to the south. The southeastern flank of the block is defined by a range of structural responses [142], which almost certainly represent a suite of buildings fronting onto the line of the *decumanus* to the southeast. Seemingly separate from this suite, in the eastern corner of the block, is a structural response of uncertain function [143]. The line of the *cardo* between this block and Block XXXV is suggested by a positive magnetic response [144].

The area labelled as Block XXXV (Figs. 42, 43) provides some of the clearest responses on the site. These structural responses can be usefully resolved into two complexes of buildings. The first of these [145], occupies the southwestern 2/3 of the area. The nature of the anomalies does not readily suggest where the primary access to the complex was located however the morphology of the responses strongly suggests that this area was the site of a public bath complex, most likely in the Italian tradition which has been argued to be the dominant model in the Iberian peninsula (Nielsen 1993). The interpretation of the structural responses in the northeastern part of the block is much less straightforward [146]. They probably represent fairly low-status housing, though there is some evidence towards the *decumanus* to the southeast that larger spaces were being enclosed. The line of the *decumanus* to the southeast is defined by a group of linear positive responses [147].

The area defined as Block XXXVI (Figs. 40, 41) is particularly fragmented by field boundaries or terraces and exhibits an interestingly unresponsive area to the east. The western corner of the block is defined by a series of structures [148], which appear to encroach on the *decumanus* to the northwest. The southern corner is partially occupied by a pair of fairly nondescript structural responses, with associated positive responses which may represent pits [149]. In the centre of the block are further structural features [150], which again are difficult to interpret with confidence but reinforce the general impression of a densely occupied urban environment. In the northern corner are a series of structural responses [151], defining four small rooms, probably accessing the *decumanus* to the northwest of the block. This block is separated from Block XXXVII by an area of positive magnetic response [152], which defines the line of the *cardo* running from the south gate and along the northeastern side of the forum area.

The area labelled as Block XXXVII (Figs. 40, 41) exhibits a fairly dense pattern of structural responses despite some interruption from modern terracing and field boundaries. The eastern corner of the area is occupied by a group of structural responses [153], which suggest buildings with relatively small rooms aligned along the *decumanus* to the northwest though with no obvious access between the buildings and the street. The features exhibited along the southeastern flank of the block resolve into three distinct structures. The southern corner appears to show anomalies

[154], which define a series of rooms and spaces fronting onto the *decumanus* to the southeast of the block. The centre of this side of the block is occupied by structural responses [155], which suggest the layout of a building with rooms fronting onto the *decumanus*, behind which are a series of rooms arranged around a central courtyard. To the north of this building are a series of structural anomalies [156], which stretch across the width of the block and demonstrate rooms and spatial subdivisions of varying sizes. The northern corner is defined by structural responses [157], which define rooms orientated inwards to the southwest and responses which suggest a colonnade along the southwestern edge of the *cardo*.

The area described as Block XXXVIII (Figs. 40, 41) ties into the excavated remains under the archaeological museum. The structural features in this area basically define two blocks of buildings. Firstly, a long, narrow series of rooms [158], accessed through a colonnaded doorway onto the *cardo* to the southwest. The second building [159], is less well understood internally but would appear to be focussed towards the *decumanus* to the southeast.

Blocks XXXIX, XXXX, XXXXI, XXXXII & XXXXIII

The area described as Block XXXIX (Figs. 42, 43) is the southernmost of the areas inside the putative line of the Roman wall-circuit. Quite a large area (*c.* 50 %) of this block was unavailable for survey as a result of modern agricultural practices. The main feature to the south of the area is a pair of negative responses [160], which are interpreted as the line of the city wall. Approximately 6m to the north of this is a *c.* 6m x 7.5m rectangular structural response [161], which probably relates to the line of the *decumanus* immediately to its north. To the east of [161] and adjacent to the line of the wall is a group of structural responses [162], for which it is not possible to propose a firm interpretation. The majority of the northwestern flank of the block is occupied by a range of structural responses [163], these almost certainly fronted onto the street but no firm evidence for entrances is visible in the geophysical survey results. These features also provide some evidence for encroachment of the buildings into the street. The northeastern end of the block is defined by a range of structures [164], which also define the continuation of the *cardo* to the northeast as far as the line of the city wall [165].

The area of Block XXXX (Figs. 42, 43) also runs along the line of the southern wall of the town. This area broadly consists of three groups of responses. The southern and northwestern sides of the block exhibit a series of structures [166], probably facing outwards onto the streets, which essentially define the limits of the area. Within this space a further series of structural responses [167], define a series of walls belonging to structures for which it is unfortunately impossible to provide a definitive interpretation. The final structural feature, to the south [168], probably represents a tower or projection which formed part of the wall-circuit. The line of the *cardo* separating this block from Block XXXXI is defined by a group of three, parallel, negative responses [169], running parallel to the ends of the blocks.

The area described as Block XXXXI (Figs. 40, 41) consisted of two narrow strips of terrain where survey was possible, separated by modern field-boundaries and abutting the open area of the *Porta Sul* excavations to the east. A positive response [170], defines the *decumanus* to the northwest. The southern and central part of the block exhibits structural responses [171], which probably form part of a building, the nature of which is uncertain. To the southeast a further pair of negative anomalies [172], demonstrate the continuation of the line of the wall-circuit beyond the excavations. Immediately adjacent to the western edge of the excavations are a series of negative responses [173], which suggest a continuation of the buildings uncovered in the excavated area. A “T-shaped” negative response [174], appears to define the point at which the *decumanus* intersects the *cardo* running northwest from the southern gate.

The area defined as Block XXXXII (Figs. 40, 41) has been subjected to excavation across approximately half of its area. In the southern part of the block, bounded by the so-called *macellum* and the paved area inside the *Porta Sul* are a series of structural responses [175], more suggestive of garden features than the internal divisions of substantial buildings. The centre of the eastern part of the block is occupied by a group of structural responses [176], defining a series of rooms organised around a central open space. The northeastern end of the area is defined by structural responses [177], for which it is not possible to present an interpretation.

The area labelled as Block XXXXIII (Figs. 40, 41) is curtailed both to the southeast and northeast by the line of the wall-circuit. Within the northeastern part of this block are a group of structural responses [178], which probably represent buildings. The main features visible are a pair of negative responses [179], which are interpreted as the line of the wall-circuit. Immediately adjacent to the southern part of the this are a series of structural responses [180], which are almost certainly associated with the wall.

The southern extra-mural zone

The final area to be considered in this discussion of the gradiometer survey is a limited area outside the line of the wall-circuit which was also surveyed in the Autumn 2010 season (Figs. 42, 43). A number of dipolar features representing modern features are clearly visible in this area. However there are also negative responses of likely archaeological significance which broadly fall into two groups. The first of these [181], consists of a large (*c.* 7.5m x 7.5m) structural response and short associated linear feature, which are reminiscent of the sort of response expected from a mausoleum or other such structure. The second and larger of the groups consists of a series of structural responses [182], which suggest the presence of buildings in the area between the spring located just outside the survey area to the south and the wall-circuit.

Discussion of the results

The magnetometry survey of the area presumed to be within the urban footprint of Roman *Ammaia* revealed a large number of interesting anomalies with archaeological potential. Although there were restrictions in the area which was available for survey as a result of extensive modern terracing of the site and heavy overgrowth in many areas, clear results were obtained against the geological background. The vast majority of pertinent features are indicated by negative magnetic responses. These features are understood to represent structural elements of the town-plan such as buildings, and the results would suggest that they are generally constructed from materials with a lower than average magnetic response (see also II.5.e).

The positive anomalies observed within the data are probably representative of either filled stratigraphically-negative features, such as pits, ditches or robbed wall-foundations; or a build-up of organic material within structures such as the *cryptoporticus* excavated to the northeast of the extant temple podium (Vermeulen, Corsi and De Dapper 2012). Other positive features may be representative of road surfaces, utilising more highly magnetic materials for surfacing, or possibly floors/dumps of ceramic building materials such as can be seen as part of the forum-bath complex (Vermeulen, Corsi and De Dapper 2012), it should be noted however that bricks and tiles are not the predominant building materials used on the site.

The long, linear dipolar anomalies between Blocks XIX, XX, XXIV and XXV, seen in the southwestern part of the site are difficult to interpret. Their nature suggests some form of linear, highly magnetic feature however they do not conform to the expected response for a modern pipeline. Despite their apparent close alignment to the line of a known aqueduct channel, this response would not be expected from a Roman, lead, water-pipe and is inconsistent with the known response of the material forming the stone channel which has been revealed through geo-archaeological survey and excavation for a modern water conduit (for further interpretation see chapter II.2).

The overall alignment of the observed geomagnetic features appears to describe a clear structure to the remains which they represent, an orthogonal pattern consisting of 45 *insulae* arranged in 9 east-west rows of 5 blocks each. This structure, in association with the evidence from previous excavations provides a significant advance in our understanding of the Roman remains and the plan of the Roman city (see chapter III.1). The gaps between the individual blocks can convincingly be interpreted as representing the Roman street-grid and so enhance our understanding of how the city was planned and constructed. The rectilinear, negative anomalies observed across the site define structures, buildings and their internal divisions. A variety of forms are observed and further discussion of the nature of these features is presented later in this volume (section III.1.b).

However, there remain a number of questions arising from the gradiometer survey. The lack of observed anomalies in the western, and parts of the northern area of the site does not provide a clear answer to where the edge of the settlement was located in those directions (section II.5.f). In the south and east of the site, large negative anomalies appear to respect the alignment of the extant city-wall as observed at the south gate and the edge of the city to the south, and slightly less convincingly, to the east can be posited with some confidence.

The clarity of the archaeological responses to geo-magnetic survey at *Ammaia* is extremely promising and clearly provides a great deal of additional information about the Roman town, which it would not have been possible to achieve in the available time through excavation or more time-consuming, targeted geophysical survey methods such as resistivity. The exceptional clarity and coverage of the results of this survey ensure that *Ammaia* should, alongside sites such as *Falerii Novi*, *Carnuntum*, *Potentia* and Wroxeter, be seen as one of the few classical cities for which we have a relatively complete urban plan derived almost exclusively from geophysical survey (Vermeulen *et al.* 2012).

II.5.C GROUND PENETRATING RADAR SURVEY AT *AMMAIA*

L. Verdonck, D. Taelman

Introduction

After initial tests with ground-penetrating radar (GPR) had proven promising, the first systematic geophysical surveys in *Ammaia* started in May 2008. In the following years, four areas of the presumed intramural area were surveyed with GPR: part of the forum and the adjacent baths (2008), a mainly residential area west of the forum (2010), the remains buried under road N359, and part of the field south-west of the forum (2011) (Fig. 44). Because of the good depth penetration of the microwaves in the soil composed of sandy silt (see chapter II.1), GPR has delivered complementary information to the intramural fluxgate gradiometer and earth resistance surveys presented earlier.

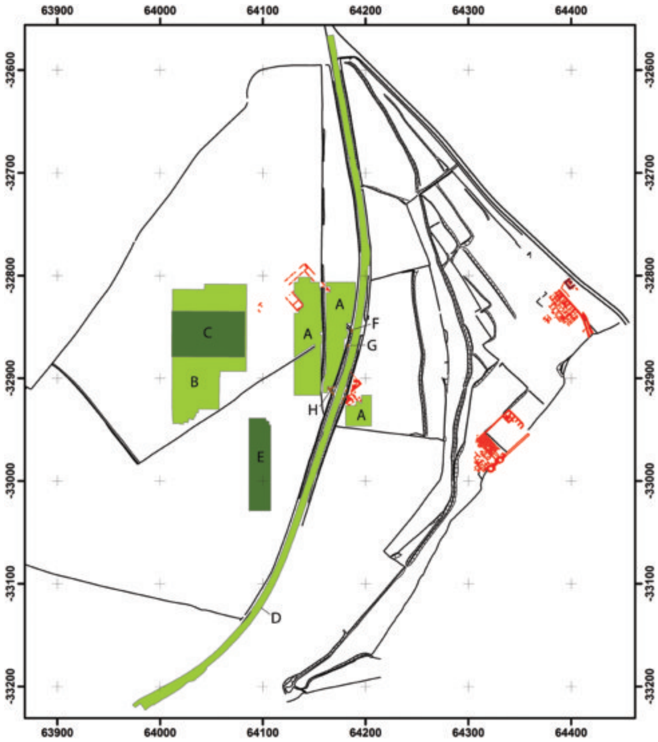

Fig. 44 Map of *Ammaia* with the areas covered by the GPR survey. A: 2008 survey area, B-C: 2010 survey area, D-E: 2011 survey. F-H: wall segments still visible above ground. The green areas indicate surveys carried out with a 0.25m transect spacing, the dark green areas were surveyed with high spatial sampling density (0.05m transect spacing). Coordinate system: PT-TM06/ETRS89.

Data acquisition

All surveys were carried out using antennas with a nominal centre frequency of 500MHz. For the forum area and the baths (*c.* 6500m² in total, surveyed in May 2008; Fig. 44, A), one individual antenna was used. The data were recorded in 'zigzag' mode, along lines with a north-south orientation marked by guide ropes, and with a spacing of 0.25m. The in-line coordinates were measured by means of an odometer wheel, triggering the system every 0.05m. The corners of the survey area were set out with a total station, using points with known coordinates in the Portuguese system. A digital terrain model (DTM) was recorded manually after the GPR data had been collected, with a density of approximately one point per 15m².

The surveys in 2010 and 2011 were conducted with a network comprising several GPR antennas (Sensors & Software Spidar system), towed behind an all-terrain vehicle (ATV). In November 2010, an area of approximately 7600m² was prospected west of the forum in north-south direction with a transect spacing of 0.25m (Fig. 44, B). For this survey, carried out in zigzag mode, the system consisted of three antennas. In the past, GPR studies have shown that, when there is a strong lateral heterogeneity in the subsurface, as is the case for most archaeological surveys, data sets collected along sparse profiles (i.e., 2D GPR surveys, with a spacing of 0.25m or more for a frequency of 500MHz) can be undersampled in cross-line direction, and the interpretation of the resulting images can be complicated. A dense spatial sampling in both horizontal directions (3D GPR survey) is critical for obtaining reliable high-resolution images of the subsoil (Lehmann 1999; Grasmueck, Weger and Horstmeyer 2005; Novo *et al.* 2010). For that reason, part of the 2010 area (71 x 44.25m) was investigated in more detail using a transect spacing of 0.05m (Fig. 44, C). Because this cross-line spacing is smaller than the physical size of the antenna (the antenna casing is approximately 0.23m wide), the scheme in Fig. 45 was used: five consecutive passes were 0.05m apart, followed by an interval of 0.55m. This 3D survey was conducted in west-east direction, along parallel transects.

Until 2011, the modern road N359 was a hiatus in the area of *Ammaia* surveyed with geophysical techniques. For the investigation of this road, GPR was the obvious method since it can be effective also on paved surfaces. As the N359 is an important connection between Castelo de Vide and Portalegre, the prospection had to occur in a short time span (one day). Because of the undulating and curved character of the more than 750m long section of the road covering the site (Fig. 44, D), it was divided in portions of 100 to 200m long, not to interrupt the line of sight between the GPR and the total station (see below). For the July 2011 campaign, a 1.5m wide array of six 500MHz antennas was employed so that the road and two narrow strips alongside it were covered by six parallel, slightly overlapping swaths. An in-line sampling interval of 0.05m and a transect spacing of *c.* 0.25m were maintained.

Furthermore, in July 2011 an area of 90 x 20.2m in the field southwest of the forum was explored, using an in-line and cross-line spacing of 0.05m (Fig. 44, E). A recording scheme comparable to the one in Fig. 45 was applied: five consecutive passes, 0.05m apart, were followed by an interval of 1.3m. The swaths were recorded zigzag, with a north-south orientation. All GPR measurements presented in this section were recorded using a stack of 8, a temporal sampling interval of 0.2 ns, and a time window of 80 ns.

During the 2010 and 2011 campaigns, a tracking total station (terrestrial positioning system, TPS) was employed. The prism was mounted above the centre of the antenna array. Position data were transferred from the TPS to the remote control on the ATV using a radio connection with a high frequency (2.4 GHz), so that no interference occurred between GPR and TPS, and then transmitted via a serial cable for fusion with the GPR data. Especially for the surveys with dense spatial sampling, where profiles have to be acquired between previously recorded ones (Fig. 45), following the theoretical transect lines as closely as possible is very important. Therefore small stakes were put along tape measures laid out in cross-line direction over the survey area every 40m, and the stakes were moved for every pass. When keeping the stakes in line, it was possible to follow the theoretical grid lines to within 0.02 to 0.04m. For the areas surveyed using the tracking total station, a DTM was recorded simultaneously with the GPR measurements, with a point density of *c.* 5 per m² (2D GPR survey) or *c.* 25 per m² (3D GPR survey) when using an array of three antennas, and with a point density of *c.* 3 per m² or *c.* 15 per m² when using an array of six antennas.

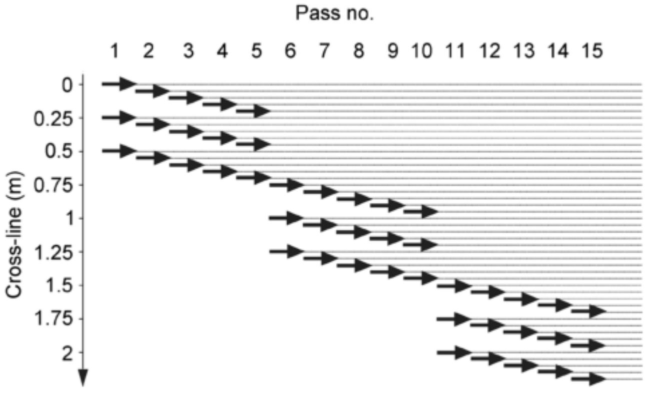

Fig. 45 Data recording scheme for a GPR system with three antennas and a cross-line separation between the antenna midpoints of 0.25m. For clarity, a different starting point has been given to each pass. For the 3D surveys, the desired transect spacing was 0.05m, so that profiles had to be acquired between previously recorded ones. Five consecutive passes were 0.05m apart, followed by an interval of 0.55m. For the 3D surveys with a six-antenna system, a comparable scheme was followed.

Data processing

For each survey, the following trace-by-trace processing scheme was followed. After elimination of the low-frequency component in the signal (the 'wow') and the alignment of the negative troughs following the start of the air-wave, the same gain function was applied to all traces to enhance later arrivals. It was based on the inverse average envelope of the amplitude of all traces in the data set, smoothed using a moving average filter with a length of 3 ns. A low-pass filter (1 GHz) was applied to suppress high-frequency noise.

Positioning

Three kinds of error in the raw TPS measurements, collected during the 2010 and 2011 surveys, were corrected. The latency is the time delay between the position measurement and its fusion with the GPR data (Fig. 46a-b). It has been shown to be constant and independent on the acquisition speed (Boeniger and Tronicke 2010). Beside a wrong in-line position of GPR traces caused by latency, cross-line deviations can arise when distance and angle measurements are not achieved simultaneously by the TPS (Stempfhuber, Schnaedelbach and Maurer 2000). For TPS instruments without an automatic synchronization tool (as for example the Leica TCRP 1201+ with CS15 remote control running Smartworx Viva software, used for the 2010 surveys at *Ammaia*) an approximation of the synchronization error can be obtained through a field test (Verdonck and Vermeulen 2011). Finally, in areas with an irregular surface, for example in the southern field (Fig. 44, E), a correction for the prism height was necessary. When the wheeled frame onto which the antennas are fixed is not on a flat surface, the prism is no longer vertically above the midpoint of the antenna array. By fitting a 2D polynomial to the prism coordinates within the area covered by the frame, the local topography was determined, and the coordinates of the antenna array midpoints were calculated (Lehmann and Green 1999).

The corrected antenna array midpoints allowed assigning coordinates to the GPR traces recorded by the different antennas in the array. Because the TPS acquires the coordinates with a frequency of 5 Hz, position data were not avail-

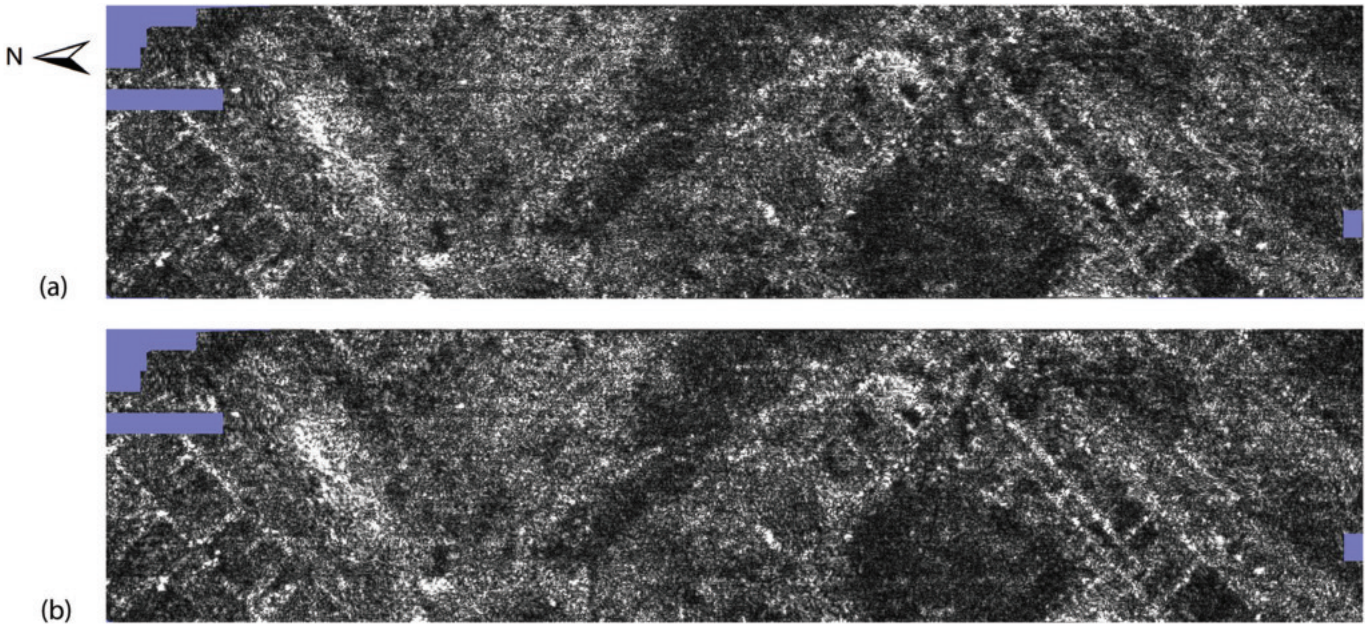

Fig. 46 GPR time-slice from the field southwest of the forum (see Fig. 44, E and Fig. 53) at 9.5-10 ns, (a) before and (b) after correction for latency. Note the improvement in the continuity of the reflections caused by the building foundations. The dimensions of the survey area were 90 x 20.2m.

able for every midpoint. The intermediate midpoints were determined by interpolation between the two nearest available TPS measurements. The coordinates of the antennas were calculated taking into account the direction of the array, determined by looking at the two nearest coordinates, and the known offset of the antennas. The data were then interpolated onto a regular grid of 0.05 x 0.05m (3D GPR survey) or 0.05 x 0.25m (2D GPR survey) using Delaunay triangulation, involving linear interpolation between the amplitudes at the corners of the surrounding triangle.

For the data from 2008, collected over the forum along guide ropes without tracking total station, fiducial marks were used to expand or contract the space between the GPR traces where necessary, so as to compensate for a possible imperfect calibration of the odometer wheel.

Reduction of linear noise

Although the antennas are tuned by the manufacturer in order to show as similar responses as possible, slightly different noise patterns were visible in transects recorded with different antennas, which provoked stripes along the survey lines in the horizontal slices, especially at larger two-way travel times. Several techniques were applied to reduce these noise stripes. The simplest way is to subtract the average of all the traces in a profile from each individual trace (background removal), but this method only partially removed the noise. Also the application of 3D frequency-wavenumber filtering (Verdonck and Vermeulen 2011) did not enable us to isolate the noise sufficiently. The best results were obtained using a filter in the space domain (Oimoen 2000; Ernenwein and Kvamme 2008). The filter consists of a one-dimensional low-pass filter applied along the survey lines, followed by a one-dimensional high-pass filter applied in cross-line direction. The resulting image containing the isolated noise is then subtracted from the original image.

Elevation corrections and migration

The two-way travel time of each recording point was adjusted so that zero time was equal to the start of the GPR signal at the transmitter (and not its first arrival at the receiver), and was subject to normal moveout corrections, removing the effect of the constant offset between transmitter and receiver (Lehmann *et al.* 1998). For the gently undulating areas of the 2008 survey and the 2010 3D survey (Fig. 44, A and C), 2D and 3D phase shift migration was used, respectively. In order to obtain a planar surface necessary for the migration, a plane was fitted to the topography, minimizing the root mean square error (Streich and van der Kruk 2006) and an appropriate static shift was applied to each trace. For the areas with more uneven topography, such as the 2011 surveys on the southern field and the road (Fig. 44, D and E), a 3D topographic migration algorithm (Lehmann and Green 2000) and a 2D phase shift migration followed by a 3D topographic correction (Leckebusch 2007a) were used, respectively. The subsurface velocity used for migration and time-to-depth conversion was estimated by applying a 2D Stolt migration algorithm to single GPR profiles, using a range of constant velocities. For the 3D data sets, migration tests were also based on time-slices. Finally, for the 2D data sets, the samples between the 2D profiles were interpolated with a bi-cubic algorithm to create pseudo-3D slices with 0.05 x 0.05m grid points.

Results and archaeological interpretation

Forum (2008 and 2011 surveys)

Until 2008, our knowledge of the forum was largely based on the excavations of the northern part of the portico, started in the first half of the 90s, and on the temple and the wall portions still visible above ground near the N359, as discussed in this volume in I.2 (see also: Fig. 44, F-H; Fig. 47b, 1-5). Fig. 47a shows four depth slices resulting from the GPR prospection. Slices A-B and D (at a depth of *c.* 0.70-0.75 and 0.40-0.45m, respectively, under the present surface of the fields) result from the 2008 survey. Slice C, representing a depth of 0.70-0.75m under the road surface, originates from the 2011 survey. These slices follow the topography.

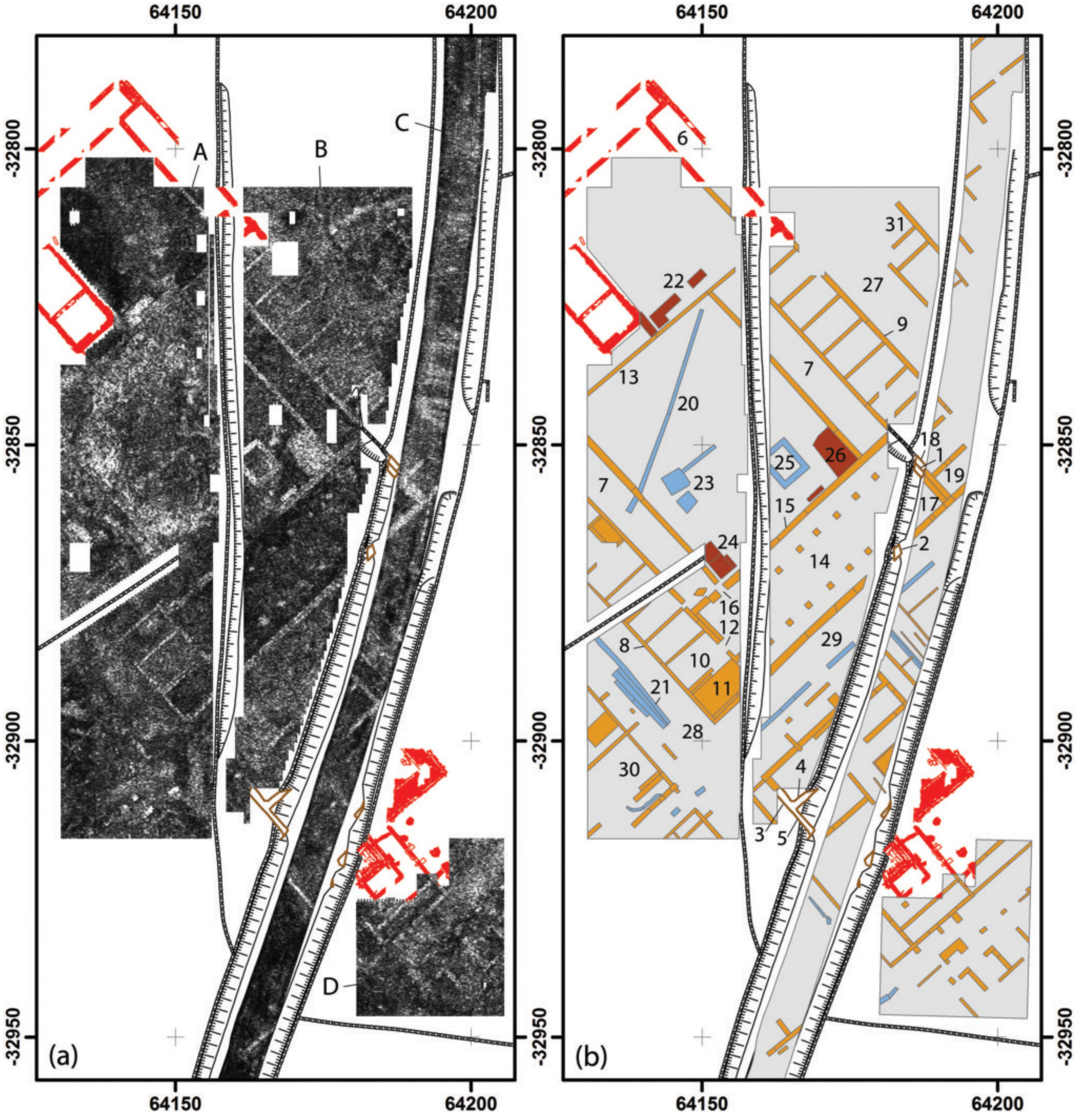

Fig. 47 (a) GPR slices from the forum and baths, at depth 0.70-0.75m (A, B and C) and at depth 0.40-0.45m (D). (b) Archaeological interpretation of the GPR data from all depth slices. Red: excavated or extant structures, grey: GPR survey area, orange: GPR anomalies interpreted as building foundations, blue: elements belonging to the water provisioning or drainage system, brown: structures on the forum. The numbers are explained in the text. Coordinate system: PT-TM06/ETRS89.

Because of the large differences in elevation between fields A and B (Fig. 47a) on both sides of the terrace wall (up to 3.5m) and between field B and the modern road, it is difficult to show the complete data set on a horizontal slice. In Figs. 47b and 48, the interpretation of the GPR data from all depth-slices (0-2m) is presented. A 3D interpretation drawing can be a complementary tool to depth-slices and vertical profiles for analyzing the relation between the structures. An example for the forum area is shown in Fig. 49.

Rather than a simple rectangular area (Mantas 2000), the GPR survey revealed a more complex plan of the forum. In the northern part, around the temple, the distance between portico no. 6 (Fig. 47b) and its northwestern counterpart (not shown) is much larger (53.5m) than in the southeastern part, where the open area between porticoes no. 7 is approximately 32m wide, due to the presence of a row of *tabernae* at either side of the forum. All *tabernae* have approximately the same inner dimensions: 8.95 x 4.9m. The reflection of their front wall appears at *c.* 0.5m beneath the present surface at the western side (Fig. 47b, no. 8), and *c.* 0.7m at the eastern side (no. 9). Above this level, the *tabernae* probably had wooden front enclosures. This gives us an indication of the walking level in the Roman period, whereas the reflection from the streets is not very clear.

The front wall of the two southwestern "*tabernae*" (nos. 10-11) provoked a much shallower reflection. Given the presence of a doorway towards the *basilica* (no. 12), these rooms may have had a different function. A floor is visible in room no. 11. As in several other *tabernae* west of the forum, the dividing walls show as double, parallel reflections. The fact that the walls do not reach the floor, is an illustration of the pull-up effect (Leckebusch 2007b): if the difference in the velocity of the GPR waves inside the wall structures (≥ 0.1 m/ns) compared to the surrounding soil (*c.* 0.075m/ns

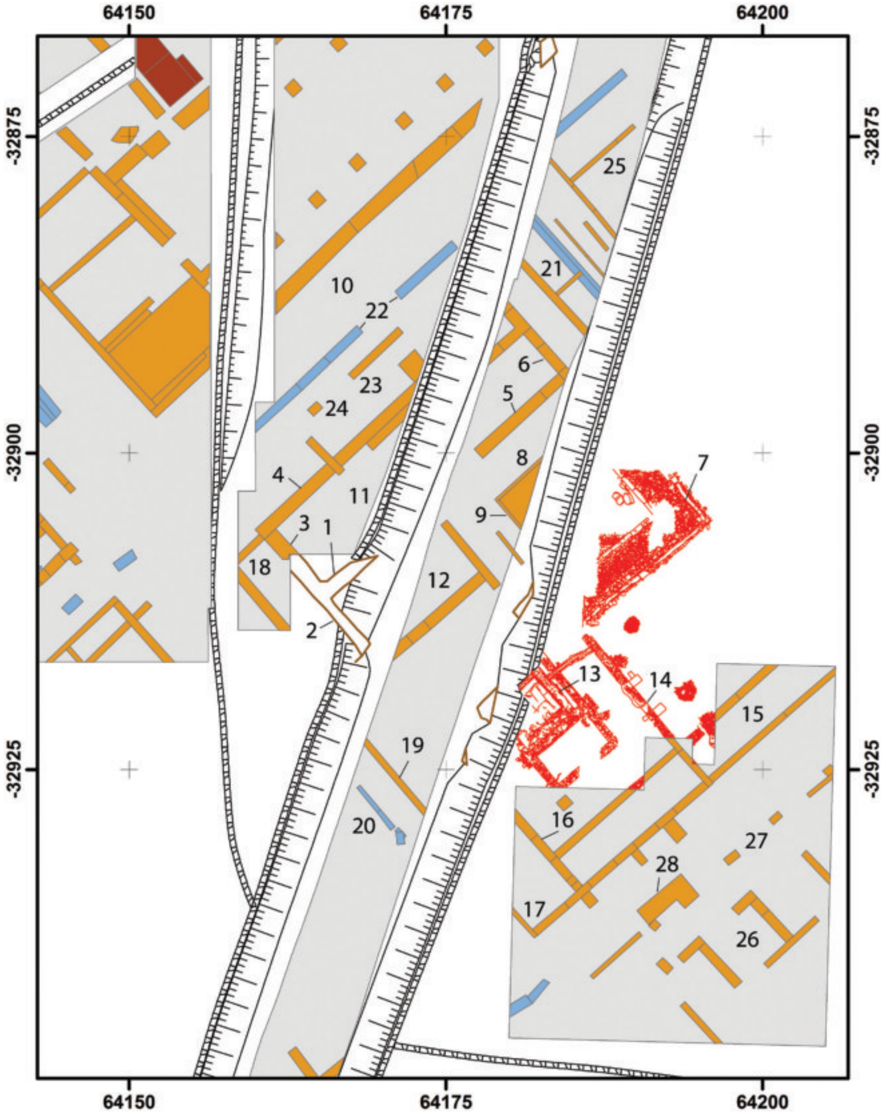

Fig. 48 Archaeological interpretation of the GPR data from the bath complex, gathered in 2008 and 2011 (road survey). Red: excavated or extant structures, grey: GPR survey area, orange: GPR anomalies interpreted as building foundations, blue: elements belonging to the water provisioning or drainage system, brown: structures on the forum. The numbers are explained in the text. Coordinate system: PT-TM06/ETRS89.

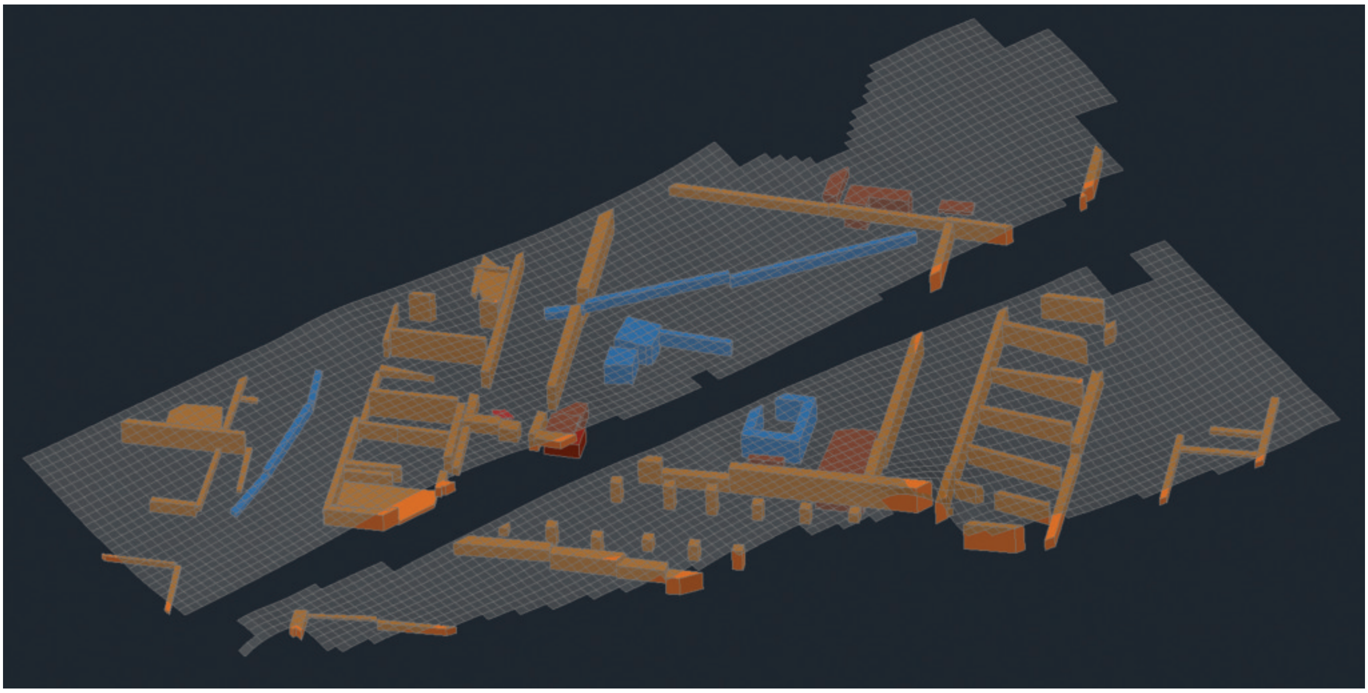

Fig. 49 Three-dimensional interpretation of the forum area with the present-day topography. Orange: GPR anomalies interpreted as building foundations, blue: elements belonging to the water provisioning or drainage system, brown: structures on the forum.

during the 2008 survey of the forum) is not accounted for in the time-to-depth conversion, the walls will not appear in their real depth.

The width of porticoes no. 7 is approximately 5.75m (between the walls), so they are somewhat wider than the excavated northern porticoes (*c.* 4.3m). A transverse structure (no. 13) separates the two parts of the forum, although it is narrower than the portico walls, which are *c.* 0.9m wide. The hypothesis concerning the presence of a basilica at the southeastern side of the forum was confirmed by the GPR results (no. 14). Its dimensions are approximately 45 by 17m, the walls are *c.* 1.2m thick. A double row of pillars or columns separates a *c.* 8m wide nave from two *c.* 3m wide aisles. In the long northwestern wall, the main entrance (*c.* 6.5m wide) and a small doorway near the western end are visible (nos. 15-16). The eastern corner of the basilica is situated under the modern road and was detected during the 2011 GPR survey (no. 17). Two structures visible in the western escarpment of the modern road can now be fitted into the basilica plan (nos. 1-2). A third feature, which still extends several metres aboveground and is also visible as a difference in elevation in the field (no. 18), is the rear wall of the *tabernae*. These continue under the modern road until the *decumanus* south of the basilica (no. 19), as at the southwestern side of the forum.

Several structures can be observed within the central square or inner area of the forum. A conduit (Fig. 47b, no. 20) is probably connected with similar feature no. 21 under the *cardo*. Other structures (nos. 22-26), some of which caused deep reflections of the GPR waves, are more difficult to interpret. Shrines, podia or statue bases are possible interpretations, some may have been part of the water provisioning system. The rest of the forum shows an enhanced but varying level of reflection, indicating a tamped surface, probably mixed with small stones. The reflection is, however, not strong enough to justify the presence of an area paved with stone slabs. East of the forum, the *cardo maximus* can be recognized (no. 27), and a *cardo* and *decumanus* delineate the forum complex to the west and the south, respectively (nos. 28-29). Here too, from the relatively weak reflections no metalled surfaces can be deduced. Along the *cardines*, less clear anomalies were detected (nos. 30-31), which can tentatively be interpreted as parts of houses surrounding the forum.

Baths (2008 and 2011 surveys)

In the field immediately west of the modern road N359, two walls belonging to the bath complex are visible above ground. One is preserved to a height of several meters, in southwest-northeastern direction (Fig. 47b, no. 4; Fig. 48, no. 1). Perpendicular to it, a wall section can be observed over a distance of more than 8m in the field and the road escarpment (Fig. 47b, no. 48; Fig. 5, no. 2). The difference in elevation between the top of wall no. 1 and the bottom of wall no. 2 (Fig. 48) is *c.* 4.8m. During the 2008 GPR survey, the extension of wall no. 2 in northwestern direction was detected over *c.* 3.7m (no. 3). It forms a corner with a weak reflection running parallel to the basilica, on the south side of the *decumanus* (no. 4). The continuation of wall no. 1 was found in 2011 under the surface of the modern road (Fig. 47a, slice

C; Fig. 48, no. 5). During the road survey several elements linking up with the excavated part of the *natatio* east of the road were discovered. A wide reflection (no. 6) is in line with excavated wall no. 7, which excavation has shown to surround the swimming pool. Furthermore, much narrower and weaker reflections (nos. 8 and 9) delineate a reflective area, which can reasonably be considered as the floor of the *natatio*. In this hypothesis, the inner dimensions of the *natatio* are *c.* 9.8 x 9.3m. Northwest of the *natatio* the surrounding platform (presumably a porticoed walkway) is *c.* 2.8m wide, southwest this is *c.* 2.25m. This is comparable to the excavated parts, which are 2.2 and 1.95m wide (southeastern and northeastern part, respectively). The whole space of the *natatio* complex forms a perfect square of 14.4m side.

If we assume that the main entrance of the bath complex was on the *decumanus* situated to the north (no. 10), room 11 probably was the *vestibulum* or the *apodyterium*. When comparing the excavated remains east of the modern road and the GPR data with excavated examples elsewhere in *Lusitania* (for example the plan of the Termas da Muralha in *Conimbriga*: Reis 2004), we can situate the sequence of *frigidarium*¸ *tepidarium* and *caldarium* in room 12 (*frigidarium*?) and between room 12 and the excavated structure no. 13, a bath covered with marble panels (*alveus* or *piscina*?).

In 2008, an area of *c.* 600m² was surveyed southeast of the excavation of the baths (Fig. 47a, slice D). This survey revealed a continuation of excavated wall 14 (Fig. 48) and two parallel walls running in southwest-northeastern direction with *c.* 2.75m spacing (no. 15), which have since then partially been excavated. Furthermore, in the GPR data a perpendicular wall is visible (no. 16) which can be associated with extant wall no. 2 in the talus. Starting from the front wall of the *tabernae* near the forum (Fig. 47b, no. 8) and the fluxgate gradiometer data further north, the axis formed by nos. 2 and 16 would seem to indicate the western edge of the bath complex. Nevertheless, GPR reflections were observed further to the west (no. 17). Also near the corner with the *decumanus* north of the baths, wall no. 18 projects further westward. These features could be interpreted as the foundations of a portico along the *cardo*, although it cannot be ruled out that they are part of the bath complex itself, possibly belonging to a later phase. An argument in favour of the latter hypothesis is that the survey under the modern road did not reveal any trace in line with walls 2 and 16, whereas a strong reflection was detected in line with the outer alignment (Fig. 48, no. 19). Feature no. 20 can probably be interpreted as a drain underneath the *cardo*, in agreement with similar rectilinear traces found near the crossroads with the *decumanus* (no. 10) north of the baths and in front of Block X. In the fluxgate gradiometer data, both walls no. 15 have been found to continue northeastward for *c.* 12m, and the outer wall then runs northwestward towards the *decumanus*, enclosing a patio or *palestra* (see sections II.5.b and II.5.f). The images from the GPR road survey revealed an area of stronger reflection with approximately the same width as this portico (no. 21). Here too, it is difficult to draw the boundary of the bath complex. Supposedly, reflection no. 22 is caused by a conduit under the surface of the *decumanus*, but features no. 23 and 24 probably belonged to buildings, as is the case further to the northeast (no. 25). The same applies to the *decumanus* running south of the bath complex. Building structures marking the southern edge of the road (no. 26) and traces of a portico (no. 27) were detected, but other reflections appear within the remaining width of the road (no. 28). Excavations have revealed here the presence of irregular late structures, encroaching the ancient street.

Summarizing, the southeastern and northeastern edges of the bath complex seem relatively certain, whereas there is more doubt on the northwestern and southwestern sides. Depending on the assumptions made, the extent of the complex can be estimated to vary between 1325m² (34 x 39m) and 1750m² (39 x 45m).

Block X (2010 survey)

In November 2010, a survey comprising parts of Blocks X and XV immediately west of the forum, as well as small parts of Blocks V, IX, XI and XIV (Fig. 44, B-C) was conducted with a transect spacing of 0.25m. In order to examine the potential of GPR for delivering high-resolution images of the underground archaeological structures at *Ammaia*, part of this area was also surveyed with a 0.05m transect spacing. Fig. 50 shows a depth slice resulting from the survey with coarse transect spacing, Fig. 52a presents the data from the prospection with dense sampling. The interpretation plan in Fig. 51 includes the detected features from all depths (0-2m) in the zone west of the forum, Fig. 52b focuses on the high-resolution survey.

The length of Block X between *cardines* nos. 1 and 2 (Fig. 51) is approximately 76.5m, its width between *decumani* nos. 3 and 4 is approximately 35.6m. It is divided lengthways in two equal halves by wall no. 5, which only shows large interruptions near no. 6. At right angles, straight walls running along the entire width of the Block occur near nos. 7 and 8. Walls no. 9-12 (Fig. 51) run only until partitioning wall no. 5. Based on these observations, a hypothesis was made that ten individual units may originally have made up Block X (see the different colours in Figs. 51 and 52b). This subdivision seems plausible given the strength and the continuity of wall reflections nos. 5-12, although it needs to be considered as a basis for the discussion of the inhabited space in Block X rather than as a final interpretation, which cannot be achieved by prospection methods only. Below, units 1-5 are discussed in detail.

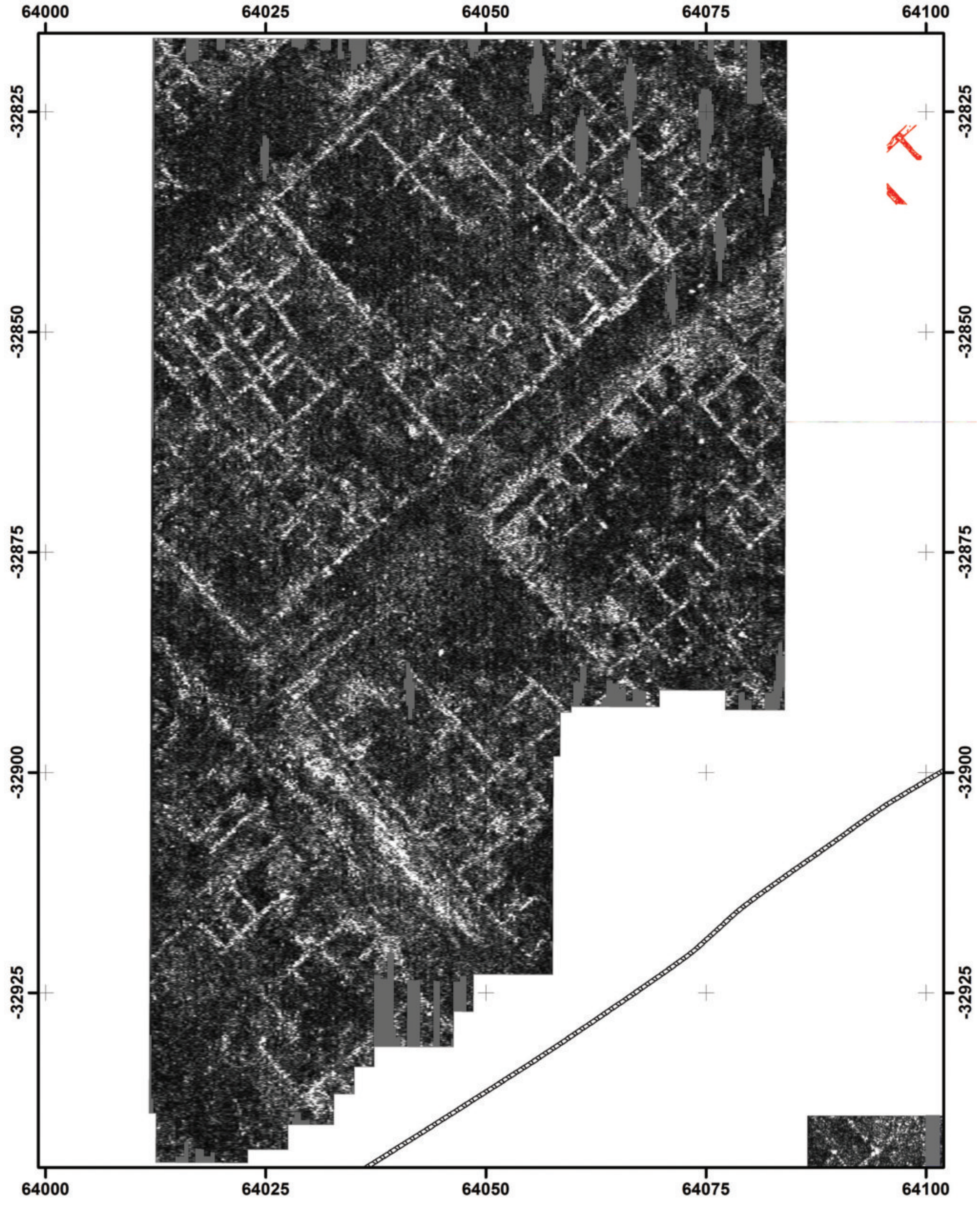

Fig. 50 GPR slice at 0.50-0.55m depth from the area west of the forum, collected with a transect spacing of 0.25m. Coordinate system: PT-TM06/ETRS89.

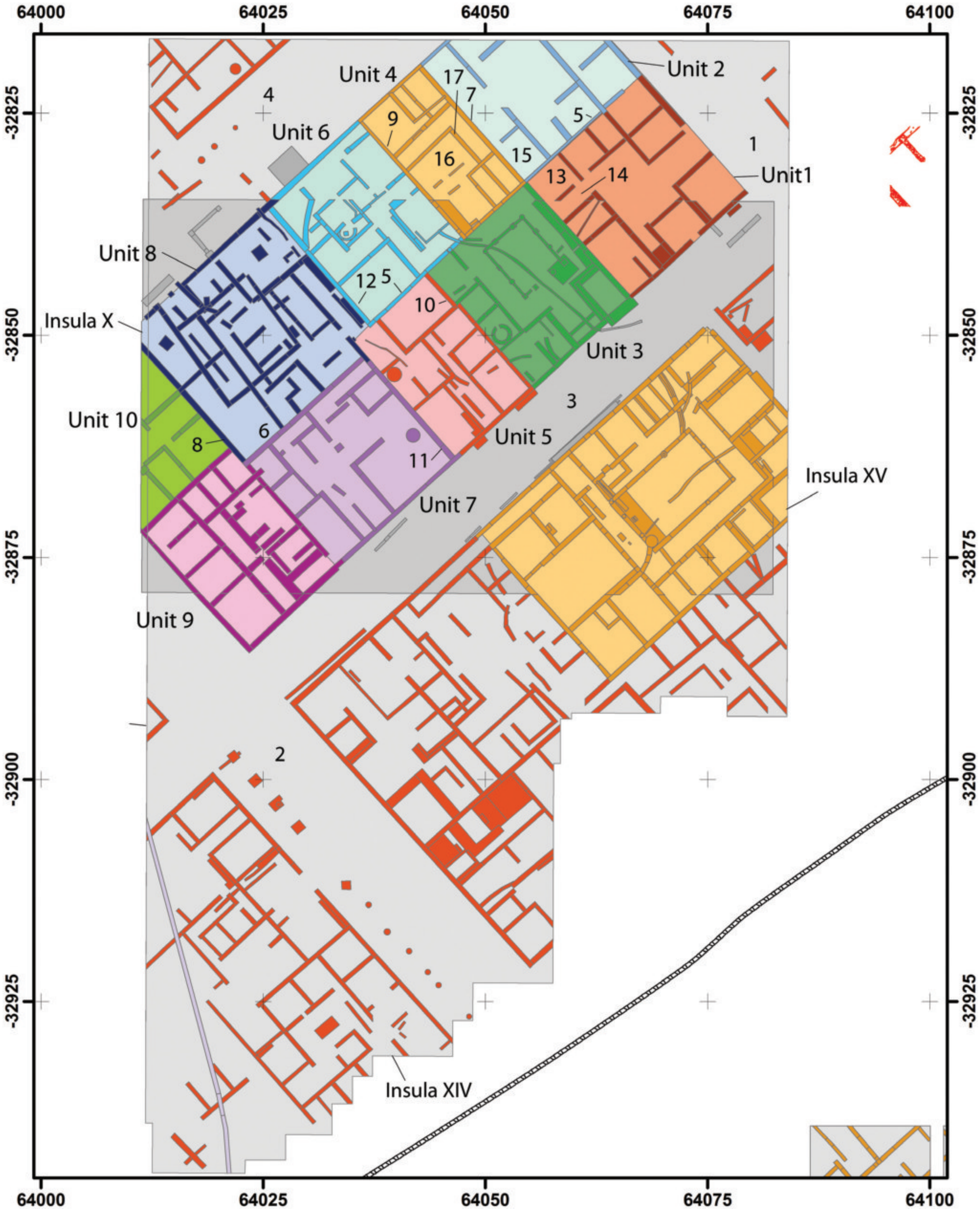

Fig. 51 Archaeological interpretation of the GPR data from the area west of the forum. Grey: GPR survey area, dark grey: high-resolution GPR survey area, red: building structures. Other wall and background colours are related to the (hypothetical) subdivision of the Blocks in housing units (see text). The numbers are explained in the text. Coordinate system: PT-TM06/ETRS89.

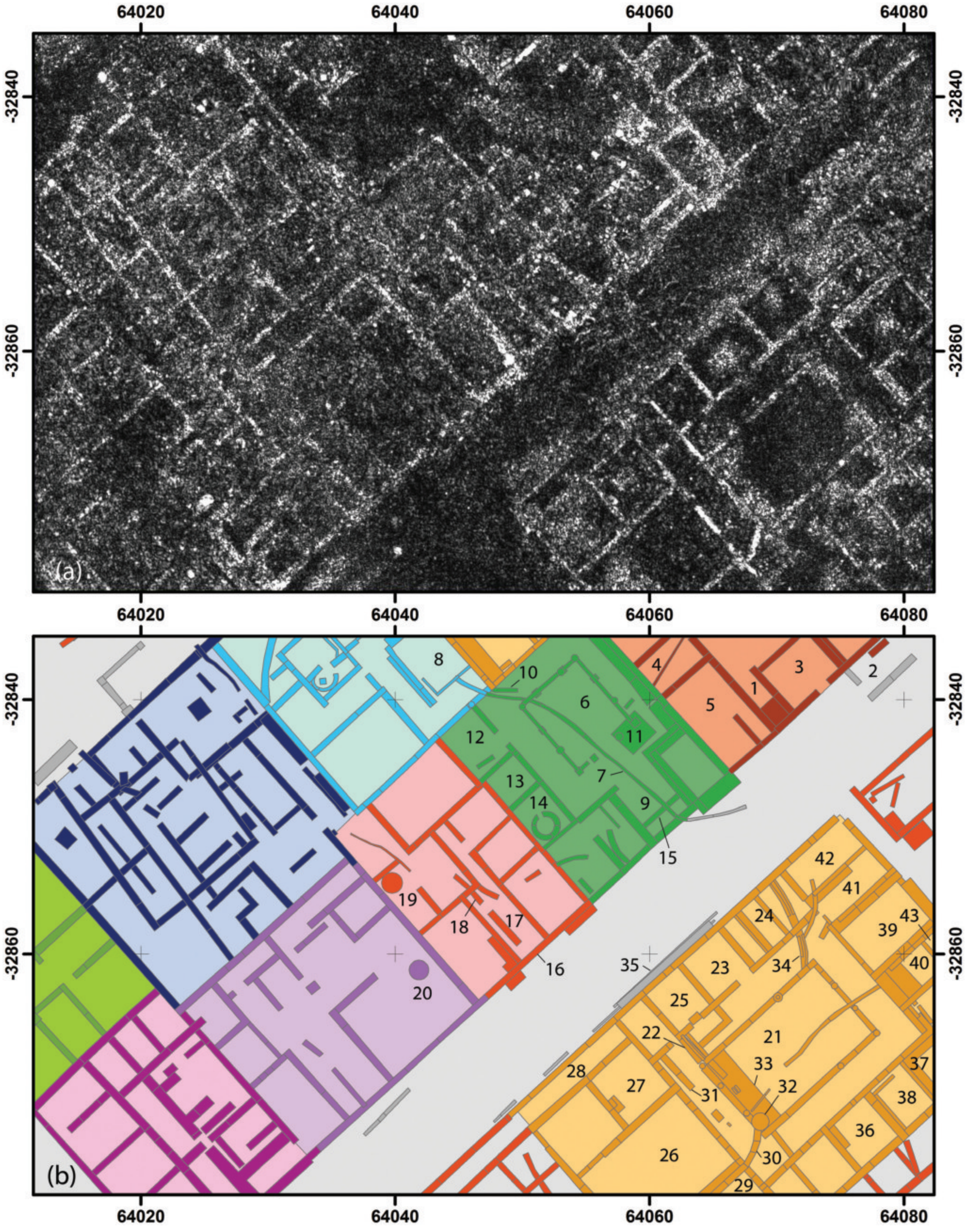

Fig. 52 (a) GPR slice at 0.60-0.65m depth from the area west of the forum, collected with a transect spacing of 0.05m. (b) Archaeological interpretation of the data, based on all depth slices (0-2m). The different wall and background colours indicate separate (hypothetical) units within the Blocks. The numbers are explained in the text. Coordinate system: PT-TM06/ETRS89.

Units 1 and 2 both have a front of *c.* 17.8m along *cardo* no. 1 (Fig. 51), and are *c.* 17.5m deep. The rooms are arranged regularly around a courtyard. Some of the rooms facing onto the *cardo* may have been *tabernae*, although this is not certain. If the front rooms were independent from the rest of the building, corridor 1 (Fig. 52b) presumably was the entrance of unit 1. Remarkably, room no. 2 (Fig. 52b) juts out of the building line along the *decumanus* more than 3m and occupies nearly half of the street, which is approximately 7.65m wide. Possibly, a portico ran along the *decumanus,* in line with the outer wall of this room, although there are few elements supporting its presence along Block X in the GPR data. In the part of unit 1 which was surveyed with 0.05m transect spacing, doorways were identified for rooms 3-5 (Fig. 52b). Through room 4, a small conduit runs towards the drain at the other side of the dividing wall with unit 3. This drain shows as a strong reflection along the entire length of the wall, probably caused by the covering stone slabs, and originates in unit 2. Given the stronger reflections, paved floors may be preserved in rooms 13 and 14 (Fig. 51), as well as in room 15 of unit 2.

Unit 3 is characterized by a *c.* 12.5 x 11.15m large *peristylium* (Fig. 52b, no. 6), with twelve columns showing as clear reflections whose average diameter is *c.* 0.55m. Some of these anomalies are square rather than circular, indicating that probably only the bases are preserved *in situ*. The maximum preserved height is *c.* 0.5m. On three sides, shallow rectilinear structures separate the area delimited by the columns from the surrounding passageways. A strong reflection (Fig. 52b, no. 7) can be recognized as a channel running from a basin in unit 6 (no. 8) through the *peristylium* and room 9 towards the street, over a visible length of *c.* 26.7m. It slopes down towards the street by an estimated 0.7m (2.5%), hence it can be considered as a drain evacuating the water from the basin in unit 6, or as an overflow of a possible cistern underneath this basin, of which no traces were detected by the GPR. At several locations, the covering slabs of this drain no. 7, as well as its sidewalls and bottom can be distinguished: the space between the sidewalls is approximately 0.25m. Near the separation wall between unit 3 and 6, another pipe branches off (Fig. 52b, no. 10). Also reflection no. 11 may be in relation to the water provisioning or drainage system, although it is impossible to interpret this further on the basis of the prospection data. In the rooms surrounding the *peristylium*, several doors were identified (nos. 12-13). The double concentric shape of the anomaly in room no. 14, with a small gap to the north, would seem to indicate a baking oven, although the fluxgate gradiometer data show only a weak positive magnetic anomaly in this location (see section II.5.b). It is unclear whether room 9 was separated from the *peristylium* by a wall. The function of a shallow anomaly running parallel to the exterior wall and leaving an interspace of *c.* 1m is also difficult to interpret (no. 15). Possibly it was a step in a strongly reflecting stone material.

The entrance of unit 5 was situated in all probability near no. 16 (Fig. 52b). The arrangement of the rooms seems regular and a few door openings can be identified. Reflection no. 17 in the corridor probably can be explained as a draining pipe. Structures no. 18 are more difficult to interpret. The circular reflection in room 19 (diameter *c.* 1.6m) perhaps represents the remains of a plinth for a baking oven. Given its dimensions and its location close to the wall, the presence of a millstone seems less plausible. Also an interpretation as an instrument for the processing of olives cannot be excluded. A similar anomaly, with a diameter of *c.* 1.5m is found in room 20 (unit 7).

The traces in unit 4 probably represent different building phases. The deepest structures show 5 or 6 rooms arranged around courtyard no. 16 (Fig. 51). In the shallowest layers, a large rectangular structure of *c.* 6.75 x 10.5m is visible, which seems to have been superimposed on the earlier structures (no. 17). This raises the question whether after this alteration unit 4 was still an independent housing unit. It is possible that units 2 and 4 became part of the same house, and other combinations are possible within Block X (for example units 1 and 3). However, as stated, it is impossible to draw further conclusions on the basis of prospection results.

Block XV (2010 survey)

Block XV has the same length as Block X, but is slightly wider: *c.* 40m. Here too, a continuous wall divides the Block lengthwise, in two unequal parts: the northwestern part, which was largely covered by the GPR prospection, is wider (*c.* 22m) than the southeastern part, where only small parts were surveyed (Fig. 51). A large part of the northwestern half of Block XV is taken up by a large *peristylium* house (Fig. 51 and 52b, coloured area), which covers a surface of 35 x 22 m (770m²). This house, which was subject to high density sampling (0.05 x 0.05m), is discussed in detail below. The rooms are arranged on the four sides of the *peristylium* (no. 21), a *c.* 12 x 7.5m large area enclosed by twelve columns and surrounded by x *c.* 2.5m wide corridor. Near no. 22, a sequence of three steps is remarkable, illustrating how the architecture was adapted to the terrain, sloping down in northeastern direction. In general, the survey of this house yielded high-resolution images after 3D migration, especially for the shallow layers. The edges of the walls are sharp, so that their width is known with relatively high precision, and most door openings can be located with high probability. Most walls are between 0.5 and 0.6m thick, although much thicker walls (up to 1m) occur in the southern and eastern part of the house (see below).

The rooms of this large house that are situated along the *decumanus* indicate two construction phases. In a second phase, rooms no. 23 and 24 were enlarged so that one room disappeared. As the outer wall seems to run continuously without any entrances from the *decumanus* (except for room 25), we can assume that all these rooms had a residential function. Moreover, the rooms do not communicate with each other, so that each room can be accessed only from the *peristylium*. Some may have been *cubicula*. A large room (*c.* 8.25 x 10.75m) centrally located in the western wing of the house, probably is the *triclinium* (no. 26). A rectangular reflection of *c.* 0.7 x 1.3m in room 27 may indicate a cooking range in stone or brick. The elongated room in front of this kitchen and the adjacent room could be interpreted as a corridor or a portico (no. 28). In room 29, a horseshoe-shaped anomaly (not shown) could point to a baking oven.

Along the wall between rooms 26 and 29, a conduit runs toward the *peristylium* (no. 30). In southwestern direction, this feature continues outside the densely sampled area (see Figs. 44, C and 51). In the data collected with coarser sampling (0.25m transect spacing), the spatial resolution is insufficient to trace the origin of the conduit. After having entered the corridor of the *peristylium*, the feature splits up into a part running immediately to the street (no. 31), and a branch discharging into a circular structure in the southern corner of the garden (no. 32). It seems logical to suppose the presence of a reservoir or cistern, which might be represented by the *c.* 1.7 x 6.8m large area of strong reflections in the western part of the garden (no. 33). This anomaly cannot be observed in strata deeper than 1.2m, although this may be due to the limited depth penetration of the GPR, or the lack of contrast between the archaeological features and the bedrock, which in this area equally provokes a strong reflection. Another drain runs from the northern corner of the garden to the street (no. 34). It is unclear whether it is connected to conduit no. 30 and reflection no. 33. Possibly, it only drained the excess rainwater from the roofs toward the street. As in unit 3 of Block X, the two sidewalls of channel no. 34 can be distinguished. This is also the case for parts of a conduit running along the *decumanus* in front of the *peristylium* house (no. 35). It can be followed over a distance of more than 50m. In the GPR images, the covering stones can be seen (often these were pieces of shale, as can be observed in the excavations of the baths), and the width of the channel can be determined to *c.* 0.15m.

The southern wing of the house mirrors the original state of the rooms along the *decumanus*: it consists of a row of five rooms of more or less equal size. As stated, some rooms have particularly thick walls (especially rooms nos. 36 and 37, as well as the rooms in the eastern wing). Although presumably nearly all the rooms in this house had floors (distinct reflections are visible for example in rooms 23, 24, 26 and 27), the southern and eastern wings are particularly interesting in this respect. The reflection in room 36 is stronger than most other floors in the house, which may indicate a different floor covering. The fact that it seems to slope down towards the middle of the room (forming a circular reflection in the lower layers) may be an effect of subsidence, as has recently been documented for Augst (Leckebusch 2011; see also Laur-Belart 1991) and for the Villa del Casale in Piazza Armerina (Cosentino *et al*. 2006). The reflective layer in room 38 is situated 0.5m deeper than most other floors in the house (*c.* 1.25m vs. *c.* 0.75m under the present surface). The walls surrounding this room show a double, parallel reflection, which, more than elsewhere in the investigated Blocks, seems to indicate two parallel walls rather than the facing on both sides of the same wall. Similar deep reflections occur in room 39 and room 40. In the latter room, which cannot be accessed from the *peristylium* but only via room 39, the reflection is particularly strong and it covers only part of the surface (an area of *c.* 1.4 by 2.5m). Towards this room, a weak linear anomaly runs from the *peristylium*. Furthermore, room 40 is shorter than the other rooms in the eastern wing (nos. 39, 41 and 42): its length is *c.* 5m instead of 7m. Behind it is situated a small room (no. 43) of *c.* 2 by 2.5m. All these elements, together with the fact that enhanced levels of magnetism were measured in rooms 36 and 37 and in parts of the eastern wing (see section II.5.b), may point towards the presence of a *hypocaustum* and/or private baths.

Survey on the southern field (2011)

As in the area west of the forum, the results of the 2011 campaign on the field southwest of the forum show a densely built, probably residential quarter of *Ammaia* (Fig. 53a). Overall, the state of preservation of the remains seems worse than in the other areas investigated by GPR. Some foundations (for example parts of the largest building discovered in this area, Fig. 53b, no. 1) are visible only in a few depth-slices, at a depth of *c.* 0.25 to 0.60m. In the western part of Block XXV (Fig. 53b, no. 2), the structures are hardly legible. Nevertheless, the general layout of this part of the town can be reconstructed. Three streets can be recognized, which are surrounded by parts of Blocks XX, XXIV, XV and XXIX. These streets can be linked to other GPR survey zones: *cardo* no. 3 with no. 1 in Fig. 51, *decumanus* no. 4 with the *decumanus* south of the baths (Fig. 48) and *decumanus* no. 5 with the street dividing the basilica from the bath complex (Fig. 48, no. 10). Underneath this northern *decumanus*, a possible element of the water provisioning or drainage system was detected (Fig. 53c, no. 6). It forms a straight line with the elements found near the baths (Fig. 48, no. 22) and with an exposed part of the aquaduct further to the southwest. On both sides of this street, remains of porticoes were observed (no. 7).

The largest building within the survey area belongs to Block XXIV. At the northeastern and southeastern side of a

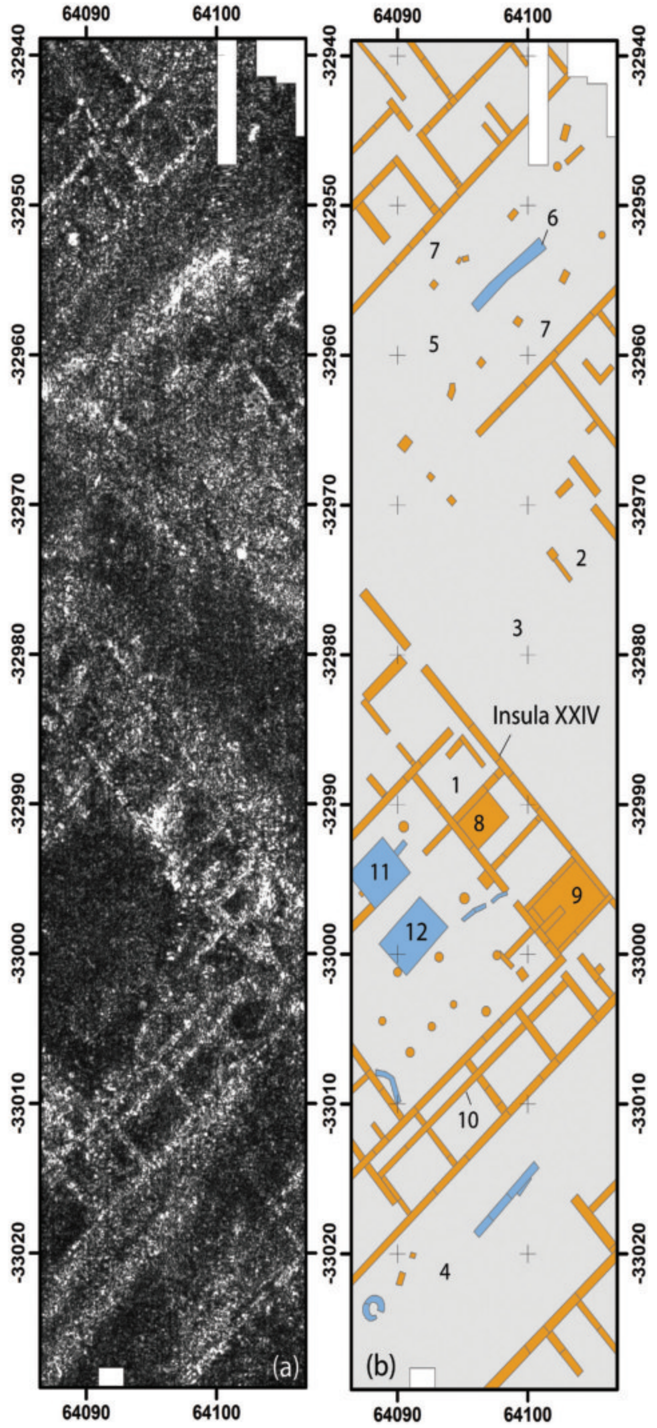

Fig. 53 (a) GPR slice at 0.40-0.45m depth from the area southwest of the forum, collected with a transect spacing of 0.05m. (b) Archaeological interpretation of the data, based on all depth slices (0-2m). Grey: GPR survey area, orange: GPR anomalies interpreted as building foundations, blue: elements belonging to the water provisioning or drainage system. The numbers are explained in the text. Coordinate system: PT-TM06/ETRS89.

courtyard, a series of rooms is situated, two of which (Fig. 53b, nos. 8 and 9) show reflections indicative of floors. As in many parts of *Ammaia*, there are features pointing to different building phases. An example is structure no. 10, although the function of this deep structure (which provoked a clear signal down to a depth of *c.* 2m) is not entirely clear. Within the courtyard several isolated reflections might indicate columns, although these seem scattered also over the middle part of the courtyard, so that they might also represent other pieces of building material. Of particular interest are structures nos. 11 and 12, which also caused reflections deeper than 1.5m and could be interpreted as cisterns.

Conclusion

After the described filtering procedures had been applied, the prospections with the GPR network comprising several antennas produced similar data quality as the surveys with a single antenna (compare Figs. 47a and 50). Unsurprisingly, the dense acquisition grid of the 3D survey (sampling distance 0.05 x 0.05m) allowed a much better resolution than the 2D survey with 0.25m transect spacing (compare Fig. 50 and 52a). This is obvious in the sharper edges of the walls and the better focused diffractions caused by individual stones. This not only improved the quality of the floor plans including drains, columns, etc., but also allowed proposing interpretations for features in the interior of buildings such as baking ovens, and setting up hypotheses about different construction phases. Because of the good depth penetration of the radar waves in the soil at *Ammaia*, the GPR technique has delivered complementary information to the fluxgate gradiometer and earth resistance surveys. This has resulted in a 3D reconstruction of the foundations around the forum, a more detailed insight in typical residential quarters, and in important information on the bath complex, hitherto hidden under the road Castelo de Vide-Portalegre.

II.5.D *AMMAIA* INTRAMURAL EARTH RESISTANCE SURVEY 2010

P. S. Johnson

Introduction

In March 2011 a limited earth resistance survey was undertaken at the Roman town of *Ammaia*. The suitability of the site for this type of investigation had been established the previous year (June/July 2010) when a study of the forum area was undertaken by the author and Jeroen Verhegge (see II.5.e). The 2011 campaign aimed to extend the area of the site covered by this technique and to target areas which would provide complementary data to the previously conducted gradiometer survey. The survey would be undertaken using a Geoscan Research RM15-D coupled with an MPX 15 multiplexer to enable measurements across multiple configurations to be recorded simultaneously, the machine was configured in the same way as for the survey in the summer of 2010 to ensure comparability between the two datasets. The 2011 season was timed to take advantage of optimal weather conditions after a wet winter and before the drying typical of the summer, which had been experienced the previous year and noted as particularly problematic. Approximately 1.5 hectares were surveyed during the 8 days of the survey, highlighting the time-consuming nature of the technique[1].

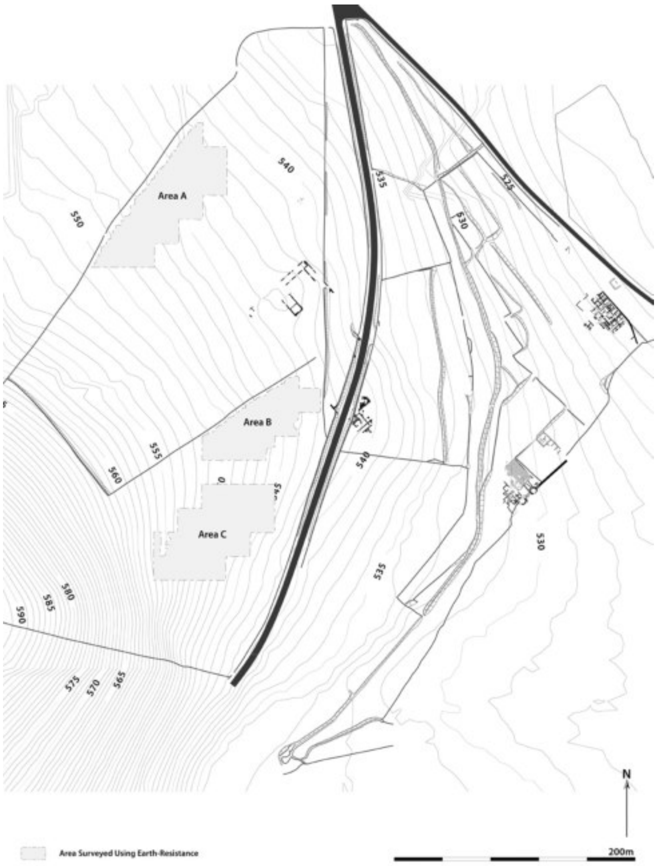

Fig. 54 Location of areas surveyed.

Survey method

The decision to use earth resistance for further survey of the site was based on its ability to provide relatively precise detail about buried structures and to indicate the presence of both stratigraphically positive and negative sub-soil features without the interference often present in magnetic data as a result of modern disturbance and the presence of ferrous material close to the ground surface (Scollar *et al.* 1990: 362ff; Geoscan 2004). The efficacy of this method in *Ammaia* was proven in the 2010 survey where despite the dry conditions a satisfactory contrast between the background resistance and archaeological features was observed in the forum area. Specific areas within the more-open, western part of the site were chosen for survey (Fig. 54). These were defined so as to cover complete blocks revealed during the geo-magnetic survey, to focus a complementary technique on areas where the magnetic data were unclear, and to provide additional data about the depth of overburden and probable site-formation processes which had taken place since the abandonment of the site.

As anticipated above, the earth resistance survey was undertaken using a Geoscan Instruments RM15-D Resistance Meter with an MPX-15 Multiplexer. This equipment, configured to produce two parallel twin-arrays, allowed the survey to be conducted more rapidly than would have been possible with just a single array. Although, as a result of the physical dimensions of the mobile probe array, the edges of the survey were more ragged than would have been experienced with a single array configuration. In accordance with the aims of the project to maintain a fairly high sample

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[1] The work in 2011 was conducted by Paul Johnson, with assistance by team members of the Radio-Past Project, the University of Évora and FCT, and by members of staff at the Museu de Ammaia.

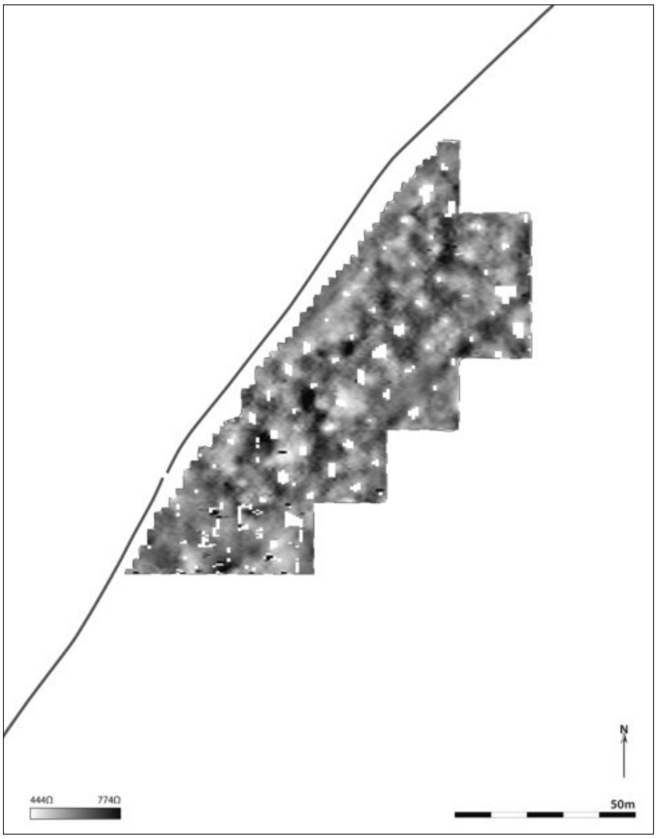


Fig. 55a Greyscale plot of the 0.5m array, earth-resistance survey data from Area A.

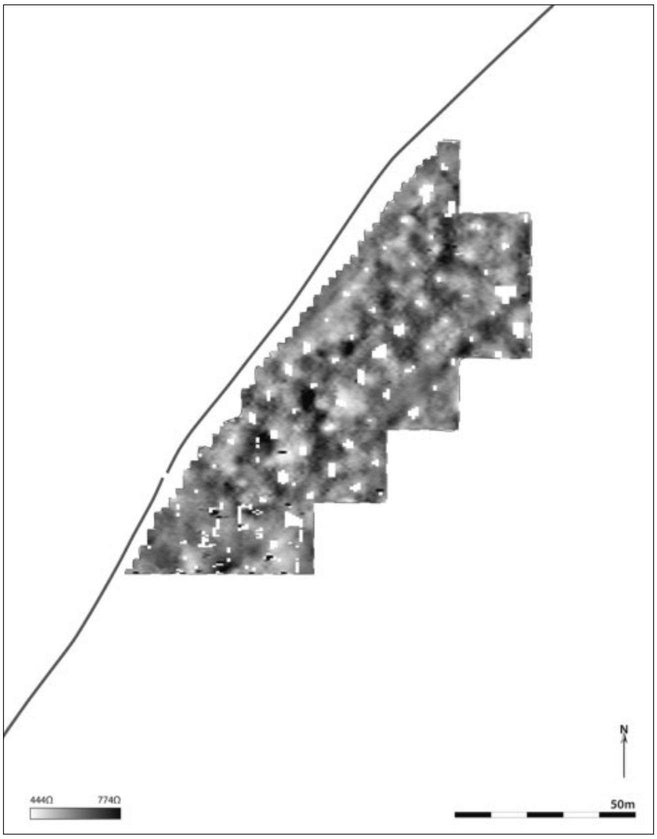


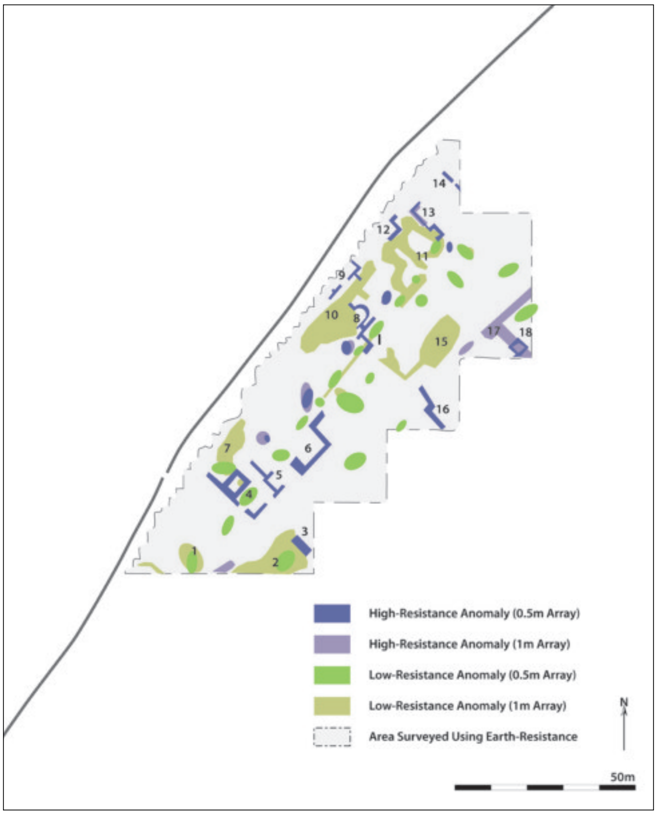
Fig. 55b Greyscale plot of the 1m array, earth-resistance survey data from Area A.

density and to maintain methodological conformity with the previous campaign, readings were taken at 0.5m intervals with two parallel twin-probe arrays along physical traverses of 1m spacing walking north. In addition at each sample location a measurement was also made across the outside probes of the array, at 1m separation, in order to gain a secondary depth profile. This enabled two sets of measurements to be collected simultaneously, one with a 0.5m x 0.5m sample density and the second at 0.5m x 1m. The geophysical survey grids of 20m x 20m were set out using a Nikon DTM520 total station on the same alignment and arbitrary coordinate system as had been used for the previous surveys, and then georeferenced into the system of fixed survey markers located around the site using Portuguese national coordinate system which is the default projection used for the wider project. Since the predominant alignments of the excavated remains were known before the initial gradiometer survey of the intramural area, the same grids as were used for that survey, orientated to transect the archaeological remains at an angle approximating 30°, were also used for this survey.

The data were processed in Geoplot 3.0 software to remove any environmental disturbances or variations produced in the course of the survey. Firstly data were manipulated to remove any distorting 'spikes' from the survey results. A high pass filter was then also used to reduce the effect of geological anomalies in the data-set. The results were exported as greyscale, raster images and inserted into the AutoCAD plan of the site for georeferencing and production of a descriptive, vector overlay. The final print-versions of these plans were elaborated and produced in Adobe Illustrator CS4.

Results

The survey covered an area of approximately 1.5 hectares in total, within the western part of the intramural urban area of *Ammaia* as defined by other surveys. Within the area surveyed, the site exhibited a good response to the geomagnetic survey and, where present, buried features showed clearly against the geological background. Electrical low-resistance features will generally suggest loosely filled, stratigraphically negative features or those which otherwise permit the passage of electrical current more easily. High-resistance features are generally interpreted as structural remains such as walls, surfaces or dense concentrations of fallen masonry. The local topsoil is fairly well-drained and so exhibits quite a high background resistance. The resolution of both arrays to 0.1Ω ensured that the archaeological features could be discerned against this background. The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High-Resistance Anomaly (0.5m Array)
High-Resistance Anomaly (1m Array)
Low-Resistance Anomaly (0.5m Array)
Low-Resistance Anomaly (1m Array)
Area Surveyed Using Earth-Resistance
N
50m

Fig. 56 Vectorised interpretative plan based on the earth-resistance survey data from Area A.

results are presented as greyscale images of the processed and unprocessed data (Figs. 55b and 55b), and as a series of numbered interpretative plans to which the following description relates (Figs. 56 and 58). As the survey was divided into three discrete areas, the conflated anomalies from both the 0.5m and 1m mobile-probe separations in each of these will first be described, followed by a synthetic discussion of their implications.

Area A

In general, this area of the site responded fairly well to earth resistance survey, though modern disturbance from the cultivation of olive trees means that the results (particularly in the eastern part of the area) are less clear than in the other areas where this technique has been applied. The southwestern corner of Area A is occupied by an area of low-resistance sub-circular anomalies [1] discernible with both 0.5m and 1m arrays. The majority of the anomalies are aligned linearly running southwest-northeast, averaging 6m x 2.5m as responses to the 0.5m array while the sub-circular response to the 1m array measures approximately 5.75m x 9m. These anomalies are bounded to the southeast by a 2.25m wide, linear, high-resistance response to the 1m array, running for approximately 6m in a southwest-northeast direction which is consistent with the line of the northernmost *decumanus* as defined by the geo-magnetic survey (see II.5.b). Immediately to the east of this is a 137.5m^2 area of low-resistance [2], the full extent of which is evident to the 1m array, the 0.5m array recorded a smaller low-resistance anomaly with an area of 23m^2 within this feature. The northeastern edge of this area of low-resistance is bounded by a strong, 2.5m wide, linear, high-resistance anomaly [3], apparent to the 0.5m array, running for approximately 6m in a northwest-southeast direction consistent with the alignment of structures within Block VI (see II.5.b).

A series of structures [4] are apparent towards the western edge of the survey area. These appear to define two interlinked or related rooms or spaces which respect the overall alignment of buildings at *Ammaia* as shown in the geo-magnetic survey. These structures are apparently shown to extend along the line of the adjacent *decumanus* by further high-resistance responses to the 0.5m array, measuring 4.5m x 11.5m [5]. Approximately 5m further to the northeast is another high-resistance feature, representing substantial structural remains [6], which appears to preclude the extension of the *cardo* running to the west of the forum from reaching the northwestern limit of the site. The area between the evidence for these structures and the edge of the survey area is occupied by an amorphous low-resistance anomaly [7], covering 19m^2 as a response to the 0.5m array, and 65.5m^2 to the 1m array

Approximately 20m to the north of the previously discussed structural features is another structure containing an apparently apsidal element, represented by a complex rectilinear, high-resistance feature [8]. This feature covers an area of approximately 46m^2, measuring 13.6m x 10.3m, and was visible only to the 0.5m array. Adjacent to the edge of the survey area, northwest of [8] are further structures [9], represented by responses to the 0.5m array. The area between these structures is occupied by an amorphous (*c.*180m^2) low-resistance anomaly [10], visible to the 1m array. This area continues to the northeast, demonstrated by a 196m^2 low-resistance response to both the 1m and 0.5m arrays [11]. The interpretation of these low-resistance areas is problematic but they may represent the effect of heavy robbing of structural material from the area either for re-use in construction or as a result of agricultural practices.

The results from the northern corner of the survey area suggest the presence of further buildings [12/13]. While these are too fragmentary for detailed interpretation, they confirm the existence, and preservation of structures in this area. Approximately 10m further to the north an interrupted, linear, high-resistance feature suggests the edge, or possibly structures within the main *cardo* running through the town from the *Porta Sul* [14].

The centre of the eastern part of the survey area is occupied by a series of low-resistance features [15], covering

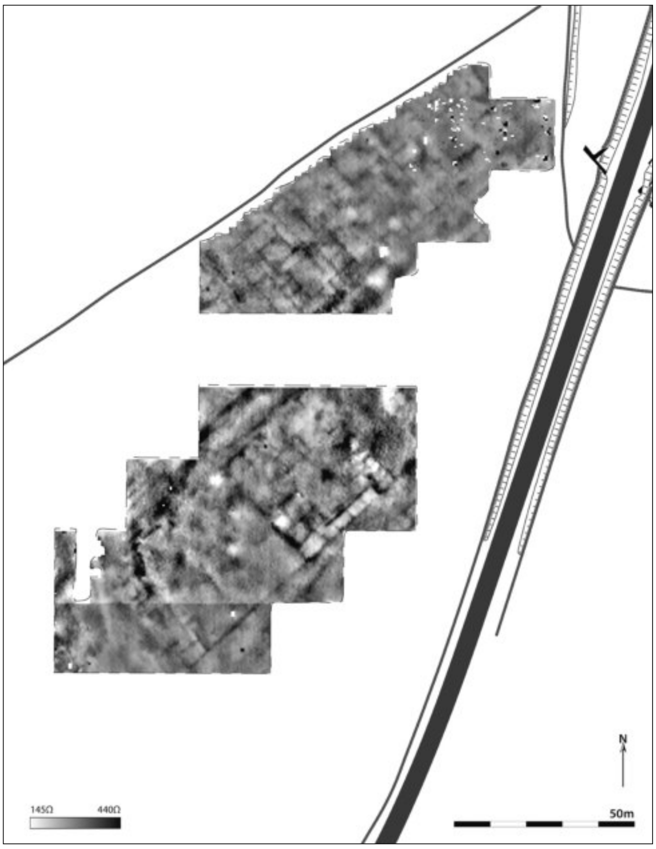


Fig. 57a Greyscale plot of the 0.5m array, earth-resistance survey data from Areas B & C

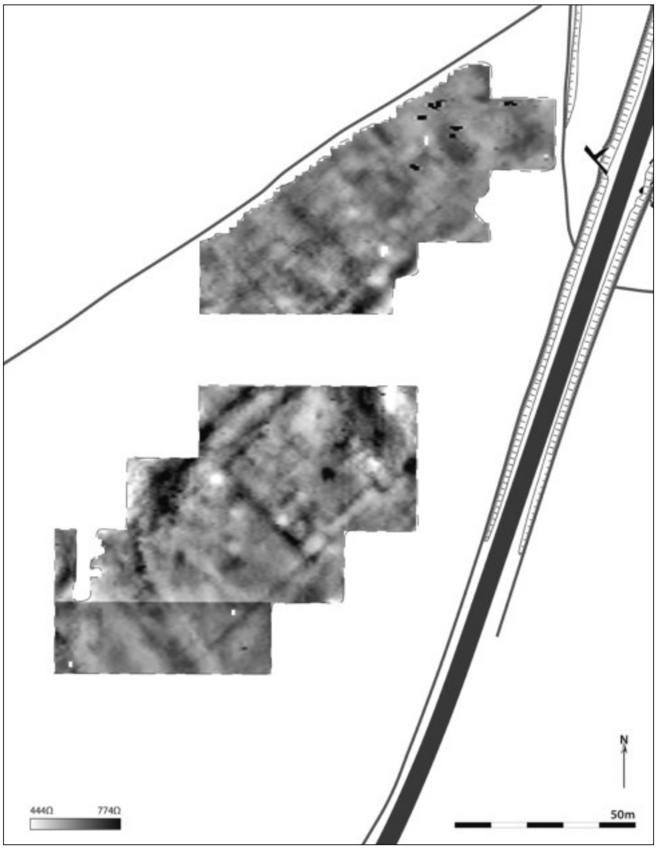


Fig. 57b Greyscale plot of the 1m array, earth-resistance survey data from Areas B & C

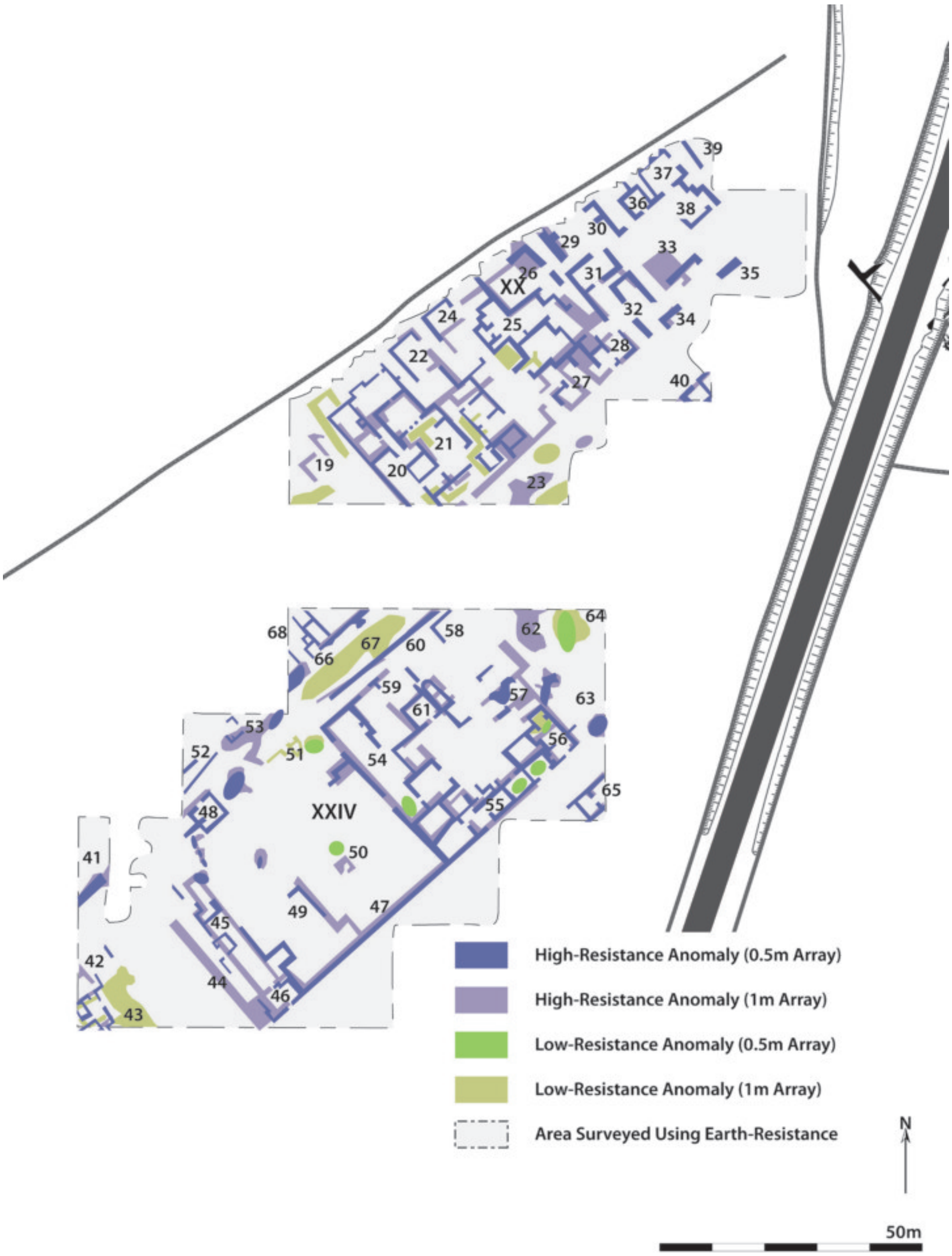
130m^2. To the south of this area is a high-resistance feature [16], which would appear to encroach on the line of the *cardo*. Whilst fragmentary and therefore difficult to interpret, this feature is aligned to the overall orientation of buildings within the city and perhaps represents structures running into or under the line of the road. The presence of structures under the road-surface can be more convincingly argued approximately 25m to the northeast. A high-resistance feature [17], which shows only in the data from the 1m array respects the orientation of the street and is aligned to its centre, in addition to running perpendicular to that alignment to the southeast. Superimposed upon the southern extent of this feature is a what appears to be a structure measuring 4m x 3.8m [18].

Area B

Area B contains much clearer responses to the earth resistance survey and was generally less subject to disturbance than the previously-discussed Area A. The westernmost part of the survey area shows only ephemeral evidence for structures [19], represented by high-resistance responses to the 1m array.

The predominant feature within the survey area is a series of rectilinear features which appear to define a contiguous and interrelated block of structures occupying the majority of the area surveyed. These structures can be broken down into three sub-divisions. The southernmost of these appears to define a series of structures covering approximately 825m^2, delineating the southwestern edge of the block [20] (Block XX on the basis of the numbering derived from the geo-magnetic survey), although these demonstrate no obvious connection between the building and the *cardo*. This subdivision contains a series of between 12 and 16 rooms, with the most significant being a courtyard or large hall measuring 12m^2 in the centre of the complex [21]. To the north of the building the rectilinear feature [22], represents a possible interconnection with the central subdivision of the block. The line of the *decumanus* to the southeast of these buildings is suggested by an irregular, high-resistance feature [23].

The link between the southern and central areas is further suggested by evidence for a structure between the two units [24]. This central part of the block consists of a complex structure [25], suggestive of a series of small, interconnected spaces. Immediately to the north is a larger, open space of 74m^2 defined by high-resistance features [26]. The southeastern face of this part of the building is defined by a series of small (*c.* 10m^2) rooms which appear to connect to the street frontage [27]. The easternmost corner of the central subdivision is defined by high-resistance features [28] which again seem to connect to the *decumanus* to the southeast and also, possibly, to the northern subdivision of the block.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High-Resistance Anomaly (0.5m Array)
High-Resistance Anomaly (1m Array)
Low-Resistance Anomaly (0.5m Array)
Low-Resistance Anomaly (1m Array)
Area Surveyed Using Earth-Resistance
N
50m

Fig. 58 Vectorised interpretative plan based on the earth-resistance survey data from Areas B & C.

This northern subdivision presents somewhat fragmentary evidence for the structures within this part of the block. The southwestern part of the building appears as a high-resistance feature [29] which delimits the northern area from the open space [26] within the central subdivision. Along with the "F-shaped" high-resistance feature [30], these appear to define rooms or spaces covering approximately 74m^2. Between this area and the *decumanus* to the southeast are a series of rooms defined by high-resistance features [31]. This space appears to connect to the *decumanus* via a pair of long, narrow corridors *c.* 12m x 3m [32]. The central part of the northern subdivision is defined by an area devoid of responses to the survey and a high-resistance feature to its southeast [33]. The edge of the block to the southeast is further delimited by the presence of two linear, high-resistance features [34/35] running along the edge of the *decumanus*. The northern corner of the survey area is occupied with a complex of structures which appears to communicate with an open area [33]. These define a series of rooms [36/37/38], ranging from 12m^2 to 36m^2. One of the larger rooms [37] also appears to communicate with the *cardo* to the northeast, which divides the area studied through the resistance survey from the central forum of the city. A linear, high-resistance feature [39], aligned with the *cardo* is probably related to the function of the road.

One final feature was recovered in Area B, a small group of high-resistance features at the southeastern limit of the survey [40]. These features demonstrate the presence of structures present in the Block (XXV) to the southeast of the *decumanus* evidenced by feature [23].

Area C

The final area under consideration was located at the western limit of the area within the town boundaries where survey is possible, beyond this point the slope of the hill becomes too steep and overgrown for the collection of meaningful data. The western part of this area exhibits a number of anomalies, separated by some distance from the rest of the responses to the survey. Most notably, the large, linear, high-resistance feature [41] is consistent with the alignment of excavated remains of an aqueduct located *c.* 7m to the northeast in an area which was not surveyed. In the southwestern corner of the survey area are what appear to be buildings represented by high-resistance features [42]. Adjacent to the northeast of these structures is a 57m^2 area of low-resistance [43].

The main evidence from the survey in this area demonstrates the presence of structures forming one of the Blocks (number XXIV) within the ancient town. As with the results from Area B, these structures can be subdivided into two interrelated but distinct areas. The southwestern part of the block is defined by the line of a *cardo* represented in the survey results by a high-resistance response to the 1m array [44] which probably represents structural features, such as a drain, below the road-surface. The actual buildings are represented by a long, corridor-like suite of rooms [45], running for *c.* 25m along the edge of the block. The southern corner of the block is defined by a 28m^2 room [46], which appears to offer access to both the *decumanus* to the southeast and the interior of the block by means of the corridor-space [45]. The division between the block and *decumanus* is further defined by a boundary or wall [47] running half of the length of the block before intersecting with the buildings in its northern part. In conjunction with a *c.* 20m^2 room to the northwest of the block [48], these features define a large *c.*1275m^2 open space occupying the majority of the southern part of the block. Within this area are two notable features. Firstly, an apparent wall [49] which divides a smaller space of *c.* 200m^2 from the rest of the open-area, and secondarily a solid, 10m^2 high-resistance feature [50] located just off-centre in the larger area. The northern corner of this space contains a small, rectilinear, low-resistance feature [51] for which interpretation is problematic. The line of the *decumanus* to the northwest of these structures is defined by a pair of linear, high-resistance features [52]. Broadly aligned to the street, these features run for *c.* 10m parallel to the edge of the structures. There is also evidence for the street itself and for the possible encroachment of buildings onto its opposite side through the high-resistance response to the 1m array and associated rectilinear features respectively [53].

The northern subdivision of the block demonstrates evidence for a more complex, but unified set of buildings than the southern area. The division between the two sub-divisions and is represented by a long, narrow (25m x 5m) corridor-room [54]. This corridor appears to provide access between the two parts of the block. This is achieved through a pair of doorways to the south and through a 35m^2 room into the northern part of the building. The southeastern flank of the building is delimited by a series of *c.* 15m^2 rooms [55] which alternately open onto the *decumanus* and into the centre of the northern part of the block. The eastern corner of the block is defined by a series of rooms [56], apparently providing access only onto the *decumanus* to the southeast. The evidence for structures along the northeastern side of the block is less clear. A group of high-resistance anomalies [57] suggest that buildings were present here but have perhaps not survived well. This hypothesis is borne out by the relatively greater extent of responses to the 1m, compared with the 0.5m, array. The northern corner of the block is also somewhat unclear. An “L-shaped”, high-resistance feature [58], measuring 4 x 5m, appear to suggest the presence of structures communicating with the *cardo* to the northeast. The northwestern flank of the building is evidenced by high-resistance features [59] suggesting the presence of rooms, and a 27m-long linear feature [60] parallel to the course of the *decumanus* to the northwest. The internal organisation of the northern part of the block is evidenced through a series of high-resistance features [61], which suggest a series of rooms (one of which appears to be apsidal) and divide the interior of the block into two large open spaces. Of these, the larger, central space is bounded by [54, 55, 56, 57 and 61] and covers approximately 220m^2. The smaller space is located towards the northern corner of the block, is bounded by [57, 58, 59 and 61] and covers an area of *c.* 170m^2.

The line of the *cardo* to the northeast of the structures previously discussed is shown as an amorphous, high-resistance response to the 1m array [62], and as a pair of high-resistance responses to both arrays [63]. Within the area of expected structures in the Block (XXV) opposite to the northeast, only an area of low-resistance [64] was apparent. In contrast, the small area of the Block (XXIX) across the *decumanus* to the Southeast revealed clear evidence for the presence of buildings [65].

The line of the northwestern *decumanus* which was shown by the high-resistance feature [53], is further evidenced by two high-resistance areas [66] running along what would appear to be the northwestern edge of the street. The large area of low-resistance [67], consistent with the alignment of the street, would suggest that the road surface and make-up has been heavily robbed. Beyond the northwestern edge of the street, the survey revealed further clear evidence for buildings in the adjacent Block (XIX), in the form of a group of high-resistance features [68].

Interpretation and discussion

The earth resistance survey of the selected areas within the site of *Ammaia* has produced some very clear results, with further implications for understanding the archaeological remains present within the town as a whole. The areas selected presented few topographical problems for the survey, with the exception of the olive trees in Area A the survey was largely clear of obstructions. Area A remains a problem for interpretation as the olive cultivation appears to have damaged the archaeological remains along the northern side of the site. However it has been possible to detect some features in that area which would confirm that the structures present on the site reach the northern limit of the land owned by the *Fundação Cidade de Ammaia*.

The structural features in the results were revealed (as expected) by high resistance responses to the survey technique and the majority of these seem to show a correspondence between those detected by application of the 0.5m and the 1m arrays. As these two arrays are effectively recording features present at different depths below the ground surface there is convincing evidence for archaeological structures and deposits existing to depths at least 1m below the current ground-surface. The correspondence between these traces would also argue for the possibility of using this technique to locate openings in the walls of buildings where gaps exist in the tracing of the 0.5m array but the 1m trace remains contiguous.

The overall alignment of the features recorded through the locations of high-resistance anomalies fits with the general layout of geophysical anomalies in the town as suggested by the previous gradiometry survey (see II.5.b), providing a finer level of detail for the structural remains than was possible using that technique. The clarity of responses to the geophysical survey techniques employed at the site once again argues for the rich potential of this site as an important archaeological resource for enhancing our understanding of town-sites in Roman *Lusitania*. The implication for these results within the context of our wider understanding of Roman *Ammaia* will be further discussed later in this volume (see Part III).

II.5.E THE FORUM INTEGRATED SURVEY

J. Verhegge

Introduction

This section presents the results of intense integrated geo-magnetic and earth resistance field-survey work undertaken in 2010 within the expected core area of the Roman town of *Ammaia*[1]. The principal aim of this particular survey was to map the sub-surface archaeological features within the areas of the forum and the important *insula* southeast of it, which excavations had demonstrated to comprise the remains of the town baths. This particular sector of the town was chosen not only because it combines a series of crucial public monuments, but also because there was good existing evidence from excavations, GPR surveys and still standing Roman structures (see section II.5.a). Focusing on this area would allow obtaining additional data, which could refine and confirm earlier evidence, but could also help adapt the on-going strategy of the new excavation program, which started in 2008. This section is however not only concerned with the presentation of our data collection, processing and initial mapping, but includes an important contribution on data interpretation going beyond simple overlays of vectorial anomaly delineations. By a selected use of several software packages that offer particular analytical tools, we aim to visualise the geophysics data from the central town area in an original and multiform way, thus redefining some of the questions asked to the archaeological record (Benech 2007).

Methods

Data collection strategy

For this higher resolution integrated approach of the central area of *Ammaia* magnetic and earth resistance survey were chosen as the preferred methods because of instrument availability, relatively quick data acquisition speed and relatively simple data processing (Gaffney, Gater and Van Ovenden 2002: 7-9). Magnetic data had already been collected in the forum area as part of the covering intra-site survey of *Ammaia* with good results (see section II.5.b). However, the sharpness of the anomalies was not optimal, due to positional errors caused by zig-zag data collection. As such this dataset was estimated inadequate for advanced data combination. No new GPR data were collected on the forum at this time (2010), as this was planned for a later campaign (see section II.5.c). As a consequence the choice of data combination methods was limited by the number and size of the available datasets. Further motivation for this selection was based on the simplicity of their application, the accessibility for archaeological geophysicists and their availability in general GIS packages.

The geo-magnetic and earth resistance data were collected by the author during a field work campaign in June and July 2010. Assistance was given by un-experienced volunteers and an experienced archaeological prospector (Paul Johnson) from the Radio-Past team.

The target area covers approximately 9000m² and consists of the forum and one *insula* south of it. Using a Nikon DM550 total station, the area was subdivided in forty 20mx20m grids, oriented north-south and crossing the walled remains at an approximate angle of 45°. The coordinates of the grids were calculated in a horizontal plane. The site relief might have caused the actual survey grids on the terrain surface to be larger, but these errors were equally spread over every grid during data collection.

The survey area was prospected magnetically again using a Geoscan Research FM256 Fluxgate Gradiometer, with sensor separation of 0.5m. The first traverse was oriented north, in order to cut the orthogonal pattern of the building remains at a 45° angle. Measurements were done on parallel traverses every 0.125m, along traverses with 0.5m separation and marked ropes were used along every traverse, improving positional accuracy. The instrument was set to its highest precision (0.1nT) and was recalibrated over the same calibration point after surveying 2-3 grids, as rising temperatures (40 + °C) could induce a drift in the measurements.

The earth resistance survey was done crossing the lines zig-zag with a multiplexed GeoScan RM15, using a PA20 multi probe array, introducing a 1mA current into the soil with a gain of x1. Using the 1m beam, 3 twin probe measurements were taken, first with 1m mobile probe spacing, followed by 2 adjacent 0.5m mobile probe spacing measurements to improve detectability. Measurements were done every 0.5m along traverses separated by 1m using marked lines and measuring tapes. The remote probes were always positioned at least 30m away from the mobile probes. Remote probe spacing was adapted to achieve normal background values when moved. The resistance survey was done in early Summer during a period of increasing drought, resulting in differing data quality.

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[1] This section is based on a MSc Archaeological Prospection dissertation, titled ‘Enhancing magnetic survey interpretation of Roman cities: geophysical data combination and archaeological feedback on *Ammaia*’, written by the author and made possible thanks to support by Div. of Archaeological, Geographical & Environmental Sciences at the University of Bradford (Dr. C. Gaffney & Dr. A. Schmidt), the Dept. of Archaeology at Ghent University (Prof. Dr. F. Vermeulen) and the Radio-Past project.

GPR data (section II.5.c) had already been collected by Lieven Verdonck in May 2008, using a Sensors & Software pulseEKKO PRO instrument with 500MHz antenna with 0,25m traverse separation. Processed 0,05m depth slices were achieved from the surveyor in a XYZ format. When combining positional errors due to the set-up of the grids (+/-0,05m), the lay-out of tapes and marked ropes within every grid (+/-0,10m) and estimated in-line positional errors during magnetic data collection (+/-0,10m), the positional accuracy closely matches the average spatial data resolution (0,25m). Positional errors impede data combination, but can only be overcome through accurate GPS positioning. As most archaeological remains (buried walls) were about 1m wide, causing even wider MAG and RES anomalies, the survey accuracy ensured sufficient overlap.

Data processing

Both raw magnetic and resistance datasets were processed using Geoscan Research Geoplot 3.xx software. Data west and east of the road were processed separately because they were collected in different grids.

Magnetic data processing was done separately for both the data west- and east of the road N359 but treated similarly. Various ferrous anomalies were removed from the magnetic data by 'despiking' multiple. Instrument drift was removed zeroing the mean of every grid. Next, a small Gaussian low pass filter was applied smoothening background values. Then, the data were interpolated to a 0,25m resolution (Fig. 59, A). Finally the processed data of both sides of the road were merged in the same master grid and exported as a xyz file in comma separated value format (csv).

After merging, the 0.5m and the respective 1m mobile probe separation ER data were 'despiked' multiple times. A median filter was applied on areas of high resistance errors. Next, a small Gaussian low pass filter was applied and the data were interpolated to 0,25m pixels (Fig. 59, B and C). High pass filtering was applied to remove geological or geomorphologic trends of decreasing background resistance values from west to east, improving image interpretation and allow quantitative data integration. Finally both non- and high-pass filtered (hp) datasets with 0.5m and 1m mobile probe separation were put in the same master grid and exported as xyz-files in a csv-format.

Data is most often only visualised for interpretational purposes. As the geophysical point-measurements were collected in a rectangular grid, the data are usually plotted as a 2-dimensiontal rectangular or squared raster image with a resolution similar to the spatial data collection resolution. The resulting pixels are mostly coloured using a usually 8-bit, preferably monochrome colour or grey scale image, stretched with a chosen transfer function using either statistical or custom set parameters as clipping values or contrast settings (Schmidt 2001b). The xyz MAG, ER and GPR data were imported to point-shapefiles using ESRI Arcmap and converted to raster files in a 32-bit TIFF raster format storing the original measurement values and an output cell size of 0.25cm to allow further GIS analysis. Their visualisation happened through a linear interpolation between the custom set clipping values and saturation of the extreme values as shown on the data plots (Kvamme 2006a).

As the magnetic and resistance data were collected in data grids presumed to be square in the horizontal plane, their corner coordinates could serve as Ground Control Points used to co-register and geo-reference the geophysical reference frame system to the Portuguese national coordinate system (PT-TM06/ETRS89) (Richards 1993: 66-67). The necessary transformation information was stored in the world file of the created images. Deviations due to local topography were compensated for every individual grid during the data collection. Basic graphical data combinations do not require the pixels to be rectified, equally sized and positioned, but as soon as more advanced mathematical operations have to be performed, the used GIS-software does require this. Therefore, the raster data could be georeferenced, rectified and resamples using an affine transformation, resulting in negligible root mean square positioning error in this phase (Schmidt 2001b). Hence, geophysical- and other spatial data sources were located within the same coordinate- and projection system as the other survey data, allowing comparison between different dataset for qualitative interpretation, but also continuous data integration.

Normalisation and standardisation

Data normalisation and standardization is necessary for operations on continuous datasets but is also useful for other data combination methods.

Normalisation includes the correction of the data distribution to a more Gaussian distribution. The skewness and curtosis of the distribution can be resolved mathematically or using a high pass filters. Because the distribution of the fluxgate gradiometer data is Gaussian, normalization was unnecessary. The earth resistance data were high pass fil-

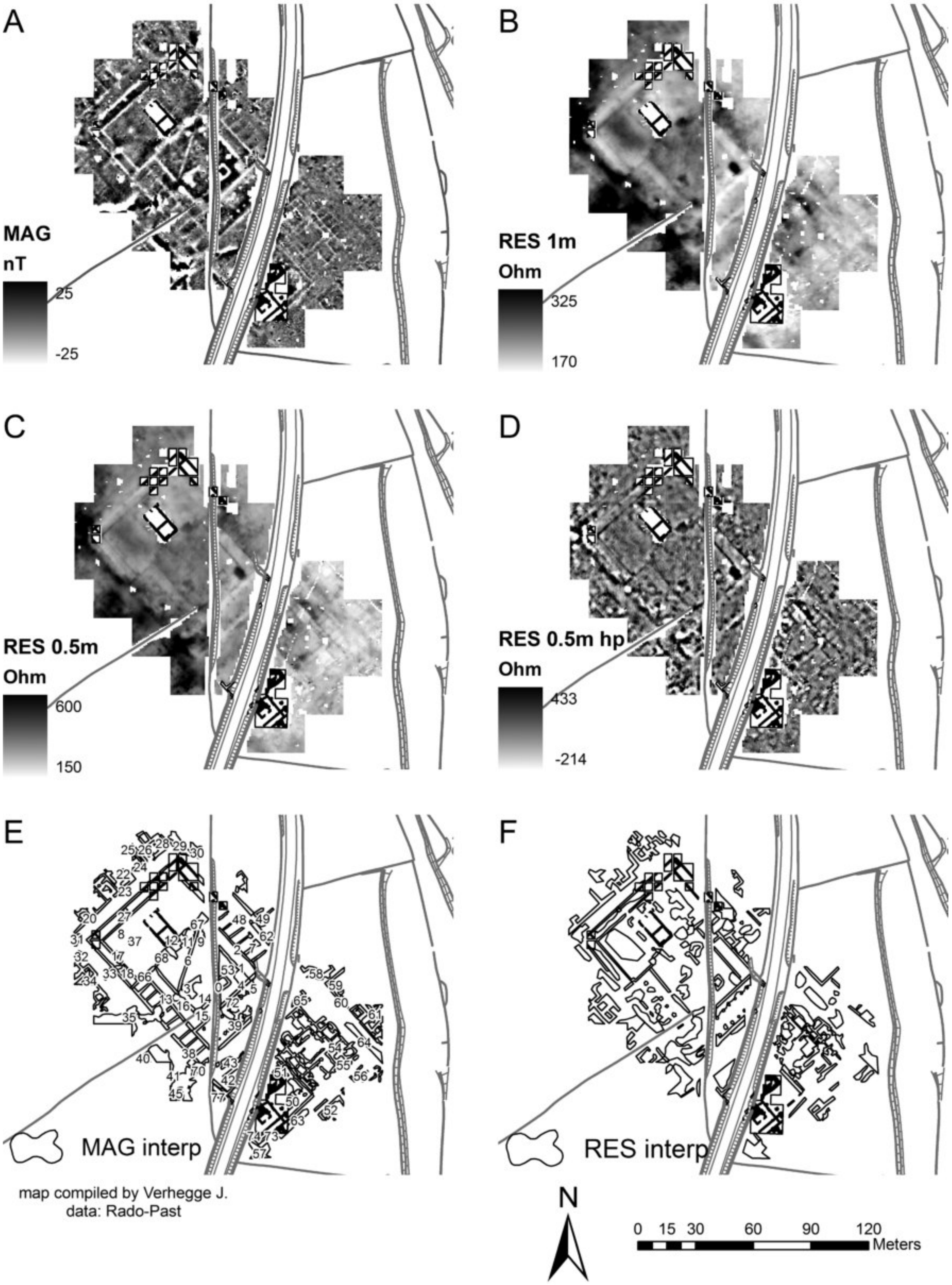

Fig. 59 A: Fluxgate gradiometer data for the forum area.
B: Twin probe electrical resistance data with 1m mobile probe separation for the forum area. C: Twin probe electrical resistance data with 0.5m mobile probe separation for the forum area. D: High pass filtered twin probe electrical resistance data with 0.5m mobile probe separation for the forum area. E: Labeled fluxgate gradiometer data interpretations for the forum area. F: Twin probe electrical resistance data interpretations for the forum area.

tered to remove low frequency trends resolving double peaking (Fig. 59, D). The GPR data were normalised reducing the dataset with the minimal value and square rooting to spread the lower values in the. This way an improved distribution was achieved.

Standardisation includes the transformation of the values to acquire 'overlapping' histograms (Richards 1993: 102-103; Piro, Mauriello and Cammarano 2000). The geophysical data of the forum of *Ammaia* were standardised until $\mu = 0$ and $\sigma = 1$ (Kvamme 2006a, 2007).

Results and discussion

Qualitatively integrated data interpretation using archaeological feedback (Fig. 59)

The manual graphical interpretation of the anomalies was achieved through their delineation in separate polygon-shapefiles for every dataset. A first data combination method would consist of a simple vector overlay of the archaeology qualitatively integrated interpretations of every dataset (Fig. 59, E and F; Kvamme 2007). Due to the large quantity of anomalies in the data, this visualisation does not really improve interpretability.

Three attributes were added to classify the polygons based on qualitative interpretations (see further): anomalies labels, simplified geophysical and archaeological interpretations. Preliminary archaeological interpretations were done on site, on paper plots. The more extensive archaeological interpretation were achieved through a holistic approach combining archaeological foreknowledge, either from previous geophysical surveys on *Ammaia*, excavations near the forum and known examples of public buildings on the Iberian Peninsula and geological or other information or other data sources to maximize the confidentiality of the interpretations (Aspinall, Gaffney and Schmidt 2008: 143). Because this mental interpretation forms a total figure using all information available to it, visual interpretation will always be better shaped than can possibly be done by any algorithmic or semi-automatic methods of data integration (Antrop 2007: 82). The communication of this interpretative process through a textual report procures it a scientific base.

The geophysical results confirmed and completed the layout of the forum as was already partly known from GPR and earlier geo-magnetic survey (see II.5. b-c and Corsi, Johnson and Vermeulen 2012). When positioned within the town lay-out, the forum seems to occupy the area of about two *insulae* and fits well within the rectangular street pattern of the city. The main road, visible as an empty space with weak positive anomaly stretches (29, 62, 64) to the east of the forum runs straight to the southern gate of the town and can be confirmed as the *cardo maximus*. The streets north and south of the forum (31, 65) are interpreted as two of the main *decumani*. Elsewhere remnants of the increased magnetically susceptible road pavement are also detected (57, 63, 65). The roads are most clear however through their lack of anomalies indicating that most of the road surfaces were taken away, as could be noticed in the excavated southern gate area (Pereira 2009) and during the 2009-2011 excavation campaigns near the bathhouse (Vermeulen, Corsi and De Dapper 2012).

In general the monumental town centre seems to follow the model of a tripartite forum, consisting of a separate free-standing temple surrounded by a colonnade-portico, a basilica hall and centrally a large open court space. Taking into account the influence of local designs, this makes the forum lay-out of *Ammaia* comparable to other fora in *Lusitania* (Mierse 1999: 95; Persichini 2012; see section III.1.a). The temple remains seem to be situated centrally in the northern ritual part of the forum and could be possibly surrounded by a *temenos*, only visible as disrupted high resistance anomalies. The soil to the north-east of the temple seems to have a low resistance, while the south-western side shows a high resistance anomaly in a semi-rectangular shape. Magnetically no difference could be observed however, except for a small negative circular anomaly (37) centrally positioned in the latter. If compared to the DEM data, the north-eastern side seems to be lower than the south-western, even though the reverse would be expected of a natural hill inclination. This could be explained by a man built terrace exhibiting differential post-Roman erosion- and colluviation processes (see chapter II.1 and Vermeulen, Corsi and De Dapper 2012), respectively at the south-western and north-eastern side of the temple podium which could also have caused the differing electrical resistance.

The north-western part of the forum seems to have been surrounded by a *c.* 4.5m wide portico (8), *c.* 28m long at the south-western and north-eastern side and *c.* 65m long at the north-western end. Geophysically, the infill of these flanks looks similar to the background values. The north-western part shows a natural fine-grained erosion filling with high magnetic susceptibility and low resistance outer side (27) on the other hand. This might be explained through burned deposit and a deeper colluvial filling towards the northern wall of the portico. The general picture of the ritual part of the forum includes a temple with associated monuments and a surrounding *temenos*, *porticus* and *cryptoporticus* (Mierse 1999: fig. 13, 21). This sacral area of the forum seems to be cut-off from the more profane part by a wall (66, 67), but the existence of these features has been disproved by the 2010-2011 campaigns of ground-truthing excavations (see section III-1-a). In front and to the east of the temple, a series of negatively and bipolar magnetic, shallow and deep high resistance anomalies indicate the presence of a staircase (12) from the temple podium to the forum square and also possible flanking platforms or statue bases (9, 10, 11, 68). Also these have been attested in the recent dig.

The forum square in front of the temple measures about 32m x 38m. The square contains a variety of anomalies. Most obvious is a linear negative magnetic anomaly (6), deviating from the town's orthogonal building and street pattern. This is only visible in the geomagnetic data, but was also remarked by the earlier GPR survey. This feature is interpreted as a relatively deeply buried stone drain. In the eastern and southern corner of the forum, two rectangular symmetric negative magnetic and high resistance anomalies, measuring about 3.5m x 6m are visible. The eastern one (1) seems to be buried less deep than the southern one (15). These features could be interpreted as basins, platforms or remains of the forum pavement in the corners of the forum.

Since the magnetic survey results show a higher magnetic gradient on the western part of the square surface (53), it could be derived that remains of the pavement or its foundation could be relatively deeply buried under slope deposits on the upper part. Furthermore, a partially 5m square positive magnetic, shallow and deep high resistance anomaly (0), shaped as a walled structure, is visible in this lower part. It seems to be positioned on the square surface and could be interpreted as a basin, but also as a built structure. Another negative magnetic and high resistance anomaly (3) on the forum square to the west of it has an irregular shape and can be interpreted in a similar way. These anomalies on the forum square could also be interpreted as remnants of late antique residential occupation of the forum. A weak negative magnetic anomaly, but shallow and high resistance anomaly (14) is interpreted as a partially demolished modern parcel boundary. Other amorphous anomalies on the forum square cannot be readily interpreted.

The forum square is flanked at the north-eastern (2) and south-western (13) sides by *c.* 5m wide and 37m long structures which can be interpreted as porticoes. They are characterized by negatively magnetic and less clear high resistance features and seem to continue up to the wall separating the upper from the lower part of the forum. South-east of the forum square and its adjacent porticoes, a series of linear negative magnetic and high resistance anomalies (4) form a rectangular building measuring about 45m x 17m. Inside this structure and about 3.5m from the side walls, a series of *c.* 1m wide rounded negative magnetic and shallow and deep high resistance anomalies (5) were detected leaving a 7m wide central aisle as an open central space for the building. These almost circular anomalies were interpreted as columns of a Roman basilica (e.g. Keay 1995: fig. 4; Mierse 1999: fig. 53). Its naves show a deep low resistance filling (39, 72) which a low magnetic susceptibility at the forum side and high magnetic susceptibility at the outer side. Analogous to the northern portico of the forum this could have been caused by differential erosion and colluviation processes or by archaeological deposits (Vermeulen, Corsi and De Dapper 2012).

Both the basilica and portico are in their turn flanked by a series of nine rooms, interpreted as *tabernae*, and detected as linear negative magnetic and pseudo-linear high resistance anomalies perpendicular to the portico (7, 38). Some of them show an increased magnetic susceptibility at the inside possibly indicating floors. The more southern spaces could, however, also be part of the basilica complex.

The *insula* south-east of the forum has been partially destroyed by modern road building and its western half was partially excavated (see chapter I.2), leaving about 60 % of it available for geophysical survey. Examination of the geomagnetic data reveals that at the south-west and south-east sides, the building block (51, 54) occupies an area that seems to partly encroach the normal street space, indicating the possible extension of an earlier structure. The filling of the thus created porticoes that belong to the identified bathhouse, which occupies the southwestern half of the block, seems to be magnetically enhanced (76). This correlates well with the deposits excavated here during the 2000-2011 campaigns. Many structures are clearly part of the *domus*-type house with *peristylium* which was detected in the north-eastern half of this *insula* and which has nice parallels elsewhere in *Ammaia* and the Iberian Peninsula (see section III.1.b). Some of the rooms joining the central courtyard of the house show a slightly enhanced magnetisation possibly due to ceramic archaeological deposits. Due to the drought during fieldwork, the earth resistance data are less sharp. Nevertheless, the results still confirm a similar lay-out and add the location of possible floors, rubble deposits or low resistance features, with a more fine-grained filling.

Most anomalies surrounding the forum and the *insula* of the bathhouse and *domus* (34, 40, 45, 49, 52, 56, 58, 59) are clearly structure-related and can be interpreted as walls. Within their context they can be seen as parts of houses. Only north of the forum, the mapped structures seem to consist of smaller rooms (20) with better preserved floors or burned deposits (22, 23, 24, 25, 26). These buildings could be more related to economic activities. The high resistance zone to the east of the forum seems more to point at structural disturbance, since it stops more or less at its western edge. This is possibly caused by erosion of the topsoil, deposited downhill, creating low background resistance. When this trend is removed, the high resistance clearly correlates to the street pattern, possibly indicating the presence of compacted material such as for road foundations. Strutt (2010) argues that the bipolar magnetic anomalies, west of the forum, are caused by near-surface geology. However, the strength and bipolarity of the anomalies rather point towards a modern ferrous origin (pers. comm. A. Schmidt).

Geophysical Data Combination

Graphical data integration (Fig. 60)

Multi-dimensional visualisation overlay

Graphical data integration methods use the varying ways in which 2 dimensional geophysical data can be presented. Hence, 3 different visual classes can be combined (Kvamme 2006b): contour lines, 3D models and colour scales including shadow plots (Schmidt 2001a). These can facilitate interpretation of what is already present in the datasets and thus enhance geophysical data. According to Schmidt (2001b), smoothly changing data presented by contours keep the data plot least complicated. Aspects to various directions can also be calculated and represented as a greyscale raster plot forming a shadow-plot, strictly speaking also using a colour scale (Kvamme 2006a).

Combination of colour and mesh models were created using ESRI Arscene. A colour representation of one dataset was draped over the base heights of another. Contours were calculated using ArcGIS spatial analyst and their intervals chosen so that archaeological anomalies coincided with a single contour. Resistance data were contoured every 50 Ohms, geomagnetic data every 40 nT. Contours from both types of data were laid over greyscale images, bipolar colour scales for geomagnetic data and colour transition scales for resistance data. A shadow plot of the magnetic data was created with ArcGIS spatial analyst, with an azimuth of 90° and an altitude of 60°.

The combined visualisation of geomagnetic data as a grey-scale and low order data such as a digital elevation model (DEM) (Fig. 60, A) or non-normal resistivity data as a 3D model enhances interpretability. Amorphous resistance anomalies can be more easily correlated to the geomagnetic data. A 2D print-out does not allow full appreciation however. An overlay of black contour lines over a different colour scaled dataset seems less appropriate as the former seems to dominate over subtle differences in colour texture (Fig. 60, B). A contour-colourscale overlay of the same datasets with high frequency variance does enhance visualisation for manual vectorisation. Combinations with shadow plots rather seem to blur the resulting picture and to reduce the information content.

It seems that multidimensional overlays of 2-dimensional datasets are harder to interpret and that the data can only be enhanced if the third dimension is used to represent a second dataset. Two datasets are maximally combined using this data combination technique, without impeding visual interpretation. Therefore, a combination of magnetic data in a greyscale and resistance data in a mesh model are preferably chosen for *Ammaia*.

Colour-composites

Another way to visualise up to 3 datasets in a single plot is through the use of colour theory (Neubauer and Eder-Hinterleitner 1997). An additive orthogonal colour composite (Red-Green-Blue) is applied in this case study (Kvamme 2006b). Hue-Saturation-Lightness colouring is only rarely used for visualisation of geophysical data (Link and Barba 2001). Various geophysical datasets were combined in the bands of a single raster dataset using the ‘composite bands’ tool in ArcGIS. First, a composite was made of the whole forum research area, with the geomagnetic data (Red), the resistivity data with 0.5m mobile probe separation (Green) and the 1m mobile probe separation (Blue) (Fig. 60, C). To include GPR data, the resistivity data with 0.5m mobile probe separation (Red) and magnetic data (Green) in the GPR survey area were extracted and combined with the GPR depth slice from 1.01m to 1.25m (Fig. 60, D).

In the first composite, the cyan colour-axis has a larger dominance due to the similarity between both resistivity datasets. The negative geomagnetic anomalies only cause disruptions in the dominating red background values. As a result wall features show up cyan and magnetic filling deposits as bright red or darker red if they are fine grained.

The second composite has a larger colour variance with a dark green background and blue spots caused by amorphous radar reflections. Walls show up in a magenta colour and infills as bright green.

This illustrates that with some mental effort these composite images allow a good assessment of the information in the combination of three datasets into a single visualisation without losing the geophysical values measured.

Translucent overlays

Computer graphic techniques in photo editing and GIS software allow the creation of translucent overlays of layers, holding a dataset in any colour. Through a 50% transparency with the layer below it, a theoretically indefinite number of datasets can be visualised as if they are blended (Eastman 2006: 67). Using a limited amount of layers, this can create a comprehensible data plot, but they are less contrasting. When overlaying a large number of datasets, the plots tend to become blurry and only the top layers can be interpreted (Kvamme 2006b; 2007). When combining the geophysical datasets of the forum, an interpretable image can only be obtained when using highly contrasting, orthogonal colours, but these are not comparable to colour composites (Fig. 60, E). The plots created through graphical data combination still require manual tracing and interpretation but do clarify correlations between the datasets. They do not require the data to be normalized but rely heavily on the chosen visualisation cut-off values.

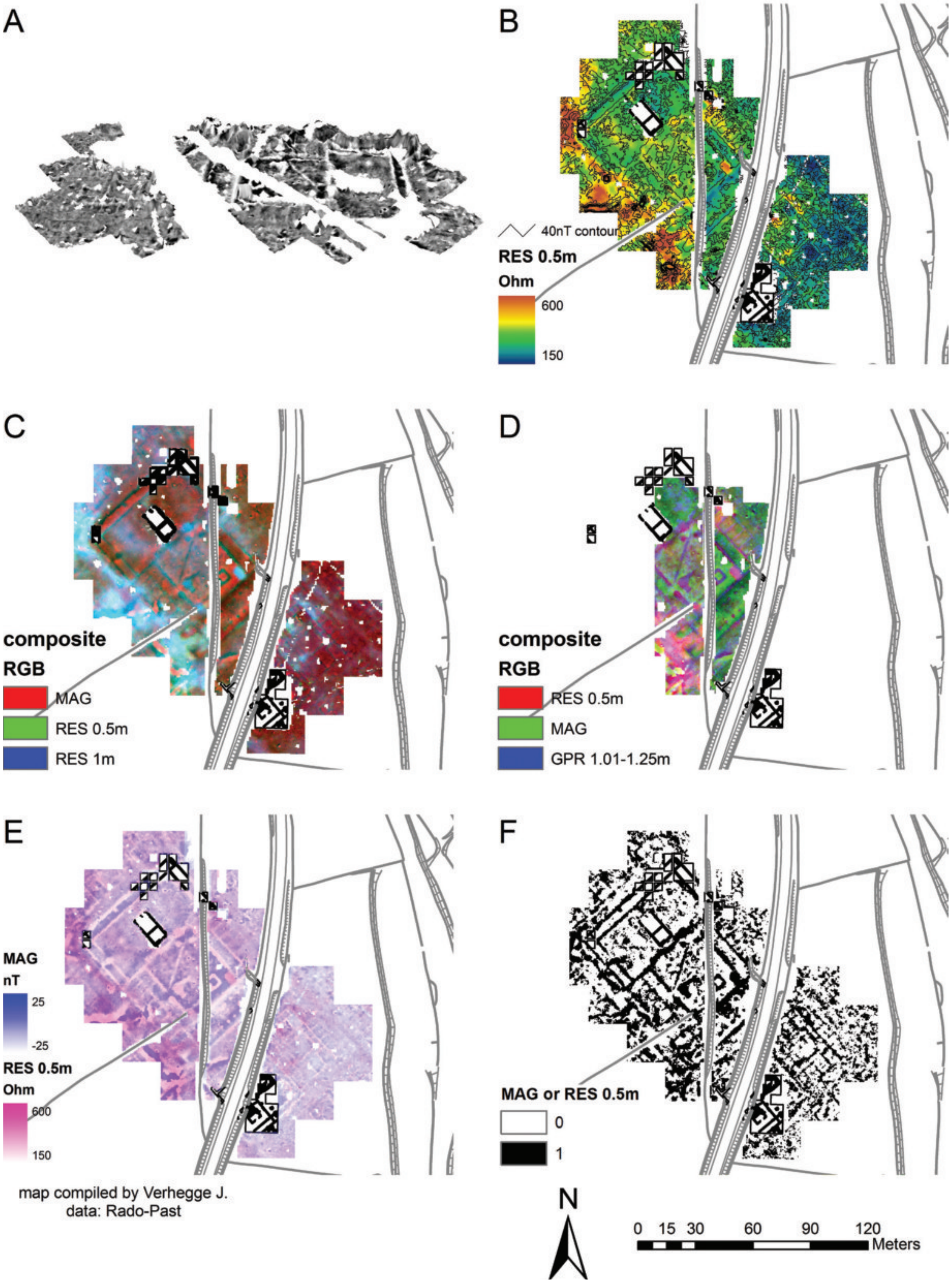

Fig. 60 A: East View of magnetic survey results as a greyscale (+/- 2SD) overlaid with a resistance survey with 0.5m mobile probe separation results 3D plot (factor 0.02). B: Magnetic data contour plot over earth resistance data 0.5m mobile probe separation colour plot. C: Red-Green-Blue composite of magnetic data on the red axis (-50 nT to 50 nT), resistance data with 0.5m mobile probe separation on the green axis (150 Ohm to 600 Ohm) and resistance data with 1m mobile probe separation on the blue axis (170 Ohm to 325 Ohm). D: Red-Green-Blue composite of resistance data with 0.5m mobile probe separation on the red axis, magnetic data on the green axis and GPR depth slices from 1.01m-1.25m on the blue axis (colour scale stretch: +/- 2 STD). E: Translucent overlay of magnetic data with 50% transparency and earth resistance data with 0.5m mobile probe separation without transparency. F: Boolean union of the magnetic and earth resistance features.

Discrete data combination

Discrete data require a rearrangement of the data into sharply defined, mutually exclusive classes removing fuzzy boundaries (De Maeyer and Antrop 2005: 138). This kind of data is relatively easily combined using GIS software.

Boolean operations on binary data (Fig. 60, F)

Boolean operations require the data to be reclassified into binary data (1 = anomaly and 0 = background value) and as such reduce the information content of the data but allow logical questions to be asked from the data. Boolean operations query data by its attributes through the actions of four logical operators. AND is used for an intersection of two variables and will create a dataset showing where anomalies are present in all datasets. OR is used for a union and will show all places where anomalies occur. Other less useful, non-integrating operators, such as NOT, show the anomalies occurring in the first dataset only, while XOR uses exclusion to create a data set with anomalies occurring in a single dataset only (Conolly and Lake 2006: 114). Alternatively, mathematical operations on binary data enrich the datasets beyond their binary nature.

For the collected datasets, it was found to be useful to create a binary dataset for highly normalised resistive or reflective and negative magnetic anomalies. However, the cut-off values chosen to determine a value as anomalous either included a lot of background noise or left out subtle anomalies. Mainly Boolean difference and intersection could help speeding up interpretations because they respectively accentuate variance within the detectability of anomalies between both datasets, illustrating larger anomaly of geomagnetic datasets, and highly correlating anomalies which were detected similarly in both datasets (Fig. 60, F).

However, the loss of information through this reclassification was not compensated by the additional interpretational value of the Boolean operations.

Continuous data combination

Computer aided image classification uses either the image characteristics themselves to define the interpretation classes (unsupervised classification), or a set of systematically structured anomaly categories is set to be recognized in the image (supervised classification) (Richards 1993: 85). In addition, these quantitative data integration methods can derive a single compound dataset from multivariate data using either local compounds working on separate data values (mathematical combination, principal component, unsupervised cluster analysis) or on focal compounds or so-called neighbourhood classifiers, using small windows of values of every dataset (supervised maximum likelihood classification) (Campbell 2002: 319-320). The advantage of these continuous data integration methods is that higher information plots are created and that subtle anomalies can be included into the analyses. But, as the numerical values of the geophysical data are used, operations on continuous data do require standardized datasets with a normal distribution.

Simple mathematical operations (Fig. 61)

Quantitative data integrations methods using simple mathematical operations such as a weighted difference between resistance and magnetic data or complicated indexes for more dimensional data, can enhance the visibility of the anomalies (Kvamme 2006b; 2007). Nevertheless, they remain mentally relatively easily interpretable (Doneus and Neubauer 1998; Piro, Mauriello and Cammarano 2000). The simplest continuous data integration happens through basic mathematical operations on the standardized and normalized geophysical data. The sum and difference were calculated using the -3 to 3 value ranges. Multiplication and division however required the values to be shifted to evade problems by ambiguous multiplications of negative numbers and negative denominators. In order to be able to compare the data plots resulting from these operations, the greyscale were adapted to the new data ranges. More advanced calculations were also done to improve the interpretability of resulting datasets.

Because the difference between GPR or resistance data and geomagnetic data (Fig. 61, A) strengthens the important archaeological features in both datasets and still visualises most important features, it could be considered well applicable on *Ammaia*. The sum of resistance and GPR data strengthens similar features as well, but the differing definition of the features between both datasets impedes good results. Since positive features are most associative with strongly negatively magnetic walls the difference between a weighted resistance and magnetic data would be even a better visualisation (Fig. 61, B).

Products and divisions mainly seem to complicate results but when negative values are shifted positively, the ratio between the resistance and magnetic data on the other hand keeps the negative magnetic values and increases their negativity slightly where high resistance anomalies are present (Fig. 61, C). The high resistance anomalies without magnetic signal are subtly represented by negative anomalies. Thus, this operation gives comparable results to the difference.

Principal component analysis (Fig. 62)

Principal component analysis (PCA) has the ability of reducing multi-parameter data dimensionality, while maximizing the variation. PCA is most useful, when high correlation between datasets is present (Richards 1993: 132-137; Kvamme 2006b, 2007).

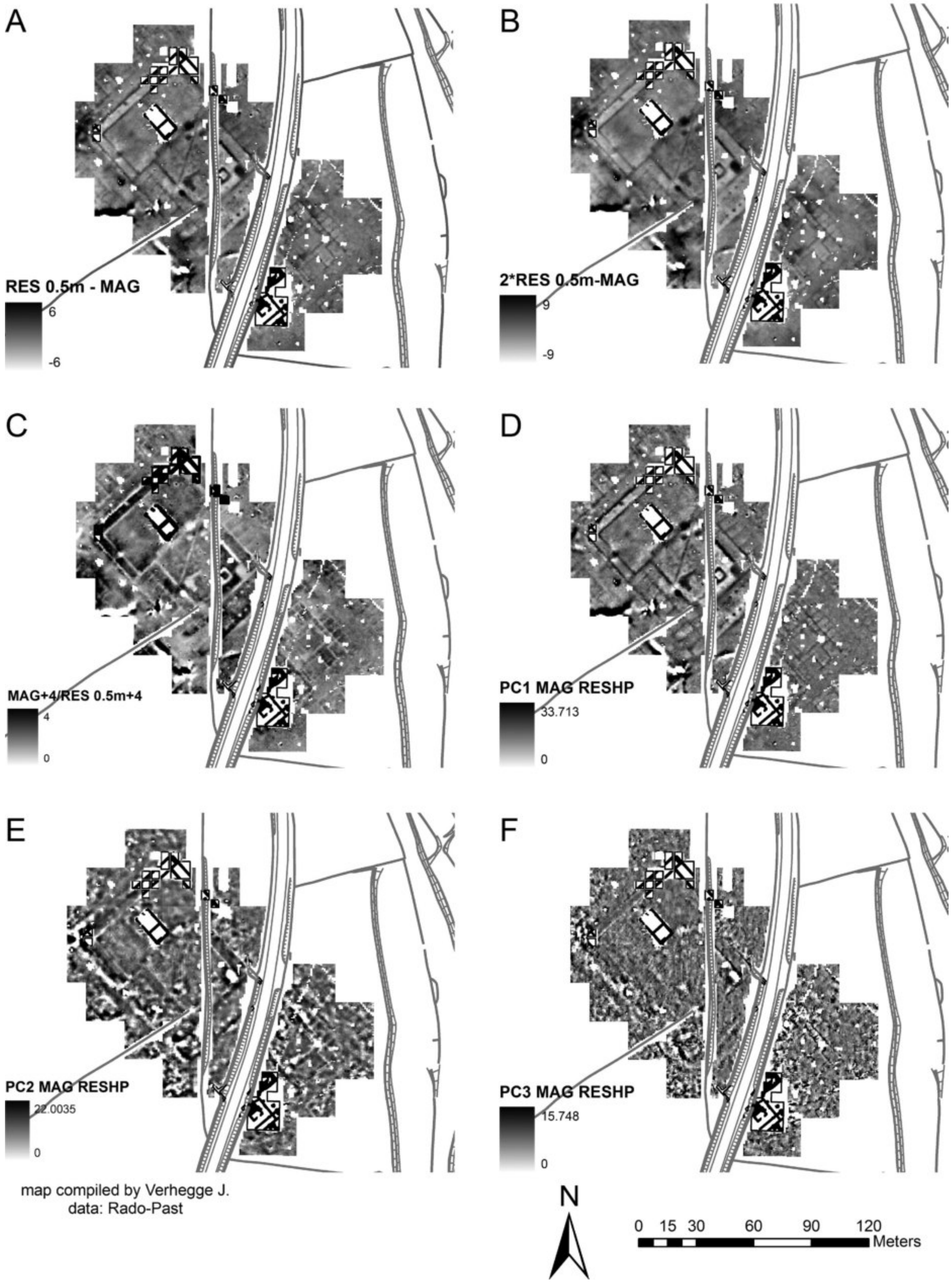

Fig. 61 A: Standardized resistance data with 0.5m mobile probe separation minus magnetic data. B: Double standardized resistance data with 0.5m mobile probe separation minus magnetic data. C: Standardized magnetic data divided by resistance data with 0.5m mobile probe separation after addition of 4 units. D: First principal component of the magnetic and both resistance datasets. E: Second principal component of the magnetic and both resistance datasets. F: Third principal component of the magnetic and both resistance datasets.

Three principal components were calculated for the whole forum area and compared to the original data. Because the forum area is covered by only three datasets, the principal component analysis of this area has no spectacular results.

Due the large variation within the magnetic data, this dataset largely coincides with the first component (Fig. 61, D) where the walled anomalies are positive. The resistance data coincide mostly with the second component (Fig. 61, E) including wall features as high resistance values. In the third component (Fig. 61, F), most of the remaining noise is visible. Only of the strongly opposing resistance and magnetic features, some remainders are visible, but these are also visible in the first and second component.

Secondly, five principal components were calculated of the extracted magnetic and both high pass filtered resistance datasets, as well as two GPR depth slices with a large information content, namely from 0.76m to 1.00m and from 1.01m to 1.25m. Here, the first component (Fig. 62, A) mainly shows the magnetic features. When these are weaker, the stronger GPR wall reflections have been added to maximize the variance. The second component (Fig. 62, B) shows the major GPR reflections and includes resistance features, absent in the GPR data. The background noise has become quite high however. The third component (Fig. 62, C) has a similar information content. Here, background noise is caused by the GPR reflections of the subsurface coming through. The fourth component (Fig. 62, D) mainly contains GPR noise and the fifth component (Fig. 62, E) shows the left resistance anomaly parts and amorphous anomalies.

Thus, when only three datasets of the whole forum were analysed, most of their variation could be stored in two components. Obviously, these components correlate with the two geophysical properties that were measured. The five datasets analysed for the GPR survey area could be reduced to three important components, where the magnetic data could be completed with the GPR data where necessary and two similar components containing mainly GPR features, with additional resistance features. The resistance features did not participate to major components, but rather filled in their gaps.

K-means cluster analysis (Fig. 63)

Cluster analyses search for homogenous clusters, distinct from others in different datasets. They can be used on non-standardized continuous data and operate rapidly on large datasets. The classification algorithm starts by an initial random selection of ‘k’ data points and adds others to the nearest clusters of these seeds. Next, the Euclidean distance from every point to the nearest mean of these clusters is calculated as well as the sum of the squared distances from the respective means. Later, these means or seeds are relocated until this sum is minimised. This algorithm is repeated until the cluster centre does not have to be moved significantly anymore. This results in a predefined number of discrete natural clusters (Conolly and Lake 2006: 145, 170-171; Richards 1993: 229-234). For geophysical data, one could argue various numbers of predefined theoretical classes (Kvamme 2006b and 2007). However, the resulting ‘k’ means-clusters still need identification (Lillesand, Kiefer and Chipman 2004: 556).

K-means cluster analysis was done on the three datasets covering the whole area. The maximum number of output clusters was varied between two and seven. Beyond this number, the cluster interpretation became nearly impossible. When 2 clusters (Fig. 63, A) are created, these correlate with strongly anomalous areas and background values. A third cluster (Fig. 63, B) consists of very strongly negative magnetic anomalies, which are mainly of bipolar nature. A fourth cluster (Fig. 63, C) includes very strongly positive magnetic parts of the bipolar anomalies. High resistance anomalies are separated with a fifth cluster (Fig. 63, D), but the weak magnetic anomaly cluster is widened, including more subtle anomalies and more noise. When six clusters (Fig. 63, E) are detected, the magnetic anomaly cluster is smaller, whilst the positive magnetic and high resistance features are split up. When seven clusters (Fig. 63, F) are defined new classes include the fuzzy anomaly edges and due to their ambiguity simple interpretations cannot be defined. Hence, unsupervised K-means cluster analysis automatically classifies the data into a predefined number of classes. Even though it is used on a limited number of datasets, this method does detect interpretable anomaly classes when a limited number of output clusters is set.

Maximum likelihood classification (Fig. 62, F)

Finally, supervised classification could provide the most useful results because it could possibly allow graphical, geophysical and archaeological interpretations of various geophysical and other remotely sensed datasets. This technique calculates the normal distribution for every predefined training sample and consequently creates equiprobability ‘contours’ of the signature clusters to put values into the most probable class (Richards 1993: 181-187). First, eight suitable classes of training sites with known interpretations were selected partially by trial and error and partially looking at differentiating characteristics. This selection contained strong wall anomalies, weaker wall anomalies, top soil infill, bipolar anomalies, road and structure associated disturbance, magnetic features invisible in resistance data due to their depth, the lower part of the forum and general background values. Next, a signature was developed for these feature types using the magnetic data and both high pass filtered resistance datasets. Finally, a maximum likelihood classification was done using this signature on the datasets using equal prior probabilities for each signature, without pixel exclusion.

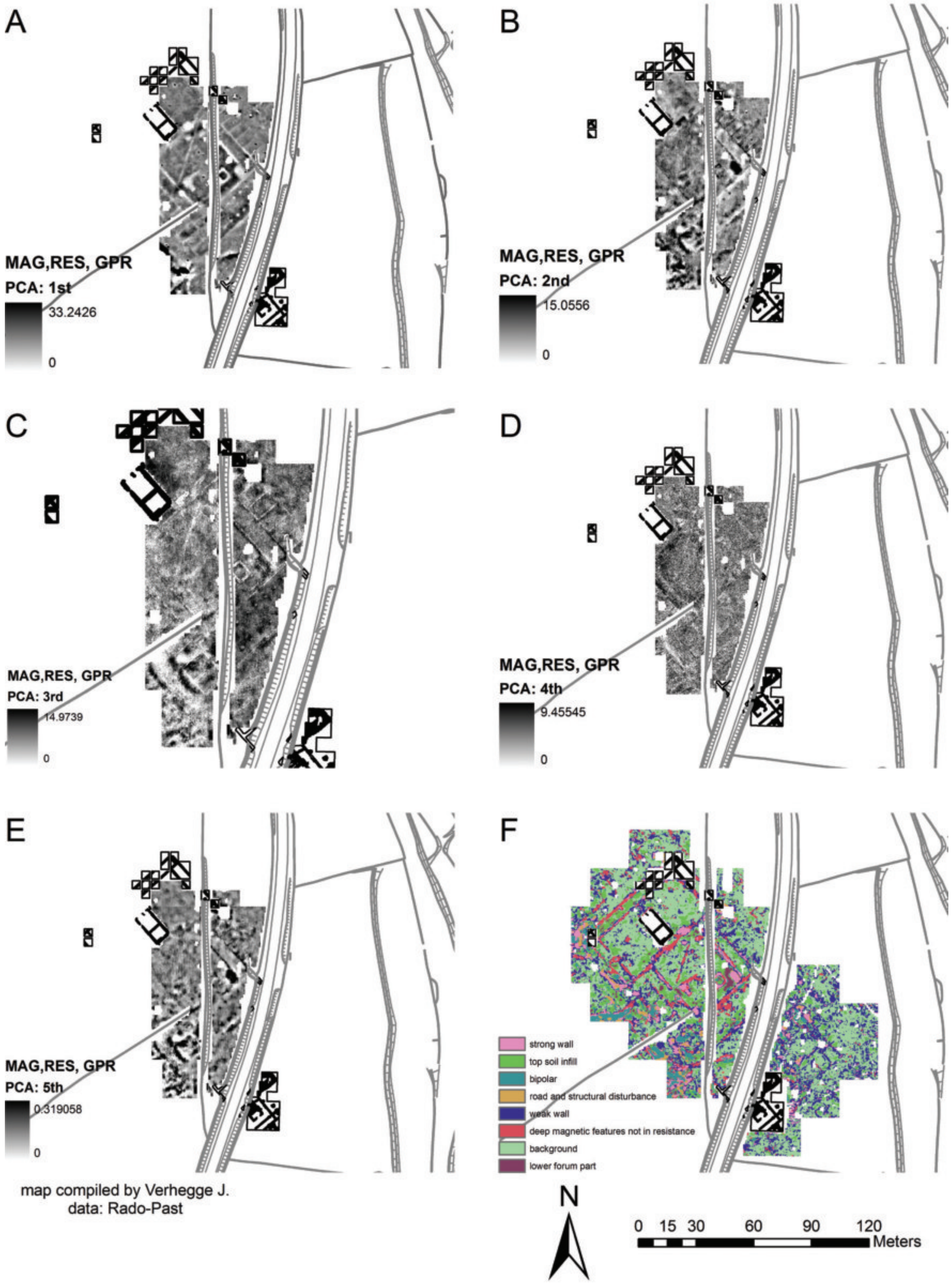

Fig. 62 A: First principal component of the magnetic, both resistance datasets and the GPR depth slices from 0.76m to 1.00m and from 1.01m to 1.25m.
B: Second principal component of the magnetic, both resistance datasets and the GPR depth slices from 0.76m to 1.00m and from 1.01m to 1.25m.
C: Third principal component of the magnetic, both resistance datasets and the GPR depth slices from 0.76m to 1.00m and from 1.01m to 1.25m.
D: Fourth principal component of the magnetic, both resistance datasets and the GPR depth slices from 0.76m to 1.00m and from 1.01m to 1.25m.
E: Fifth principal component of the magnetic, both resistance datasets and the GPR depth slices from 0.76m to 1.00m and from 1.01m to 1.25m.
F: Supervised classification of magnetic and resistance data covering the whole forum area.

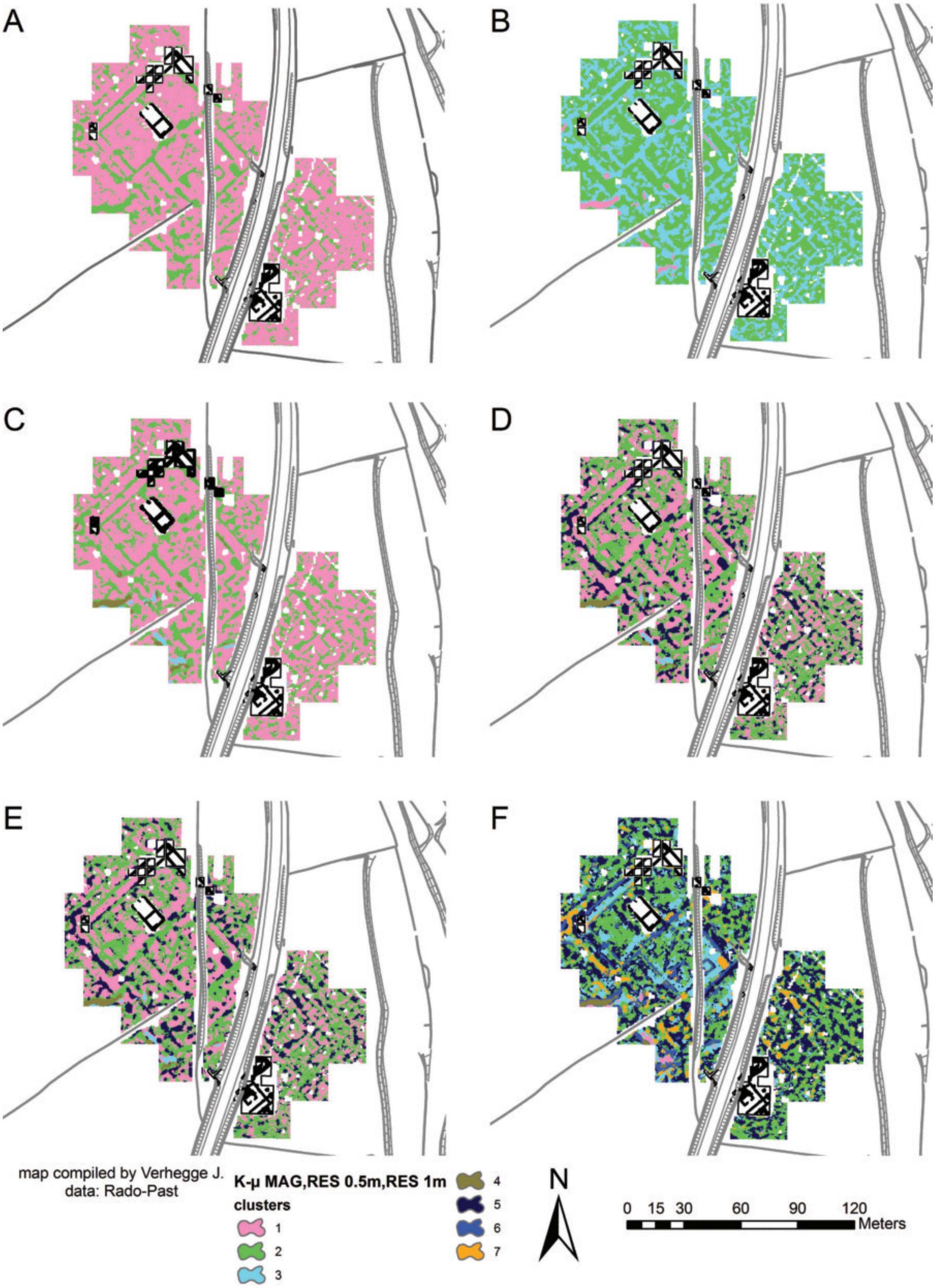

Fig. 63 A: K-means cluster analysis of magnetic and both resistance data allowing maximum 2 clusters. B: K-means cluster analysis of magnetic and both resistance data allowing maximum 3 clusters. C: K-means cluster analysis of magnetic and both resistance data allowing maximum 4 clusters. D: K-means cluster analysis of magnetic and both resistance data allowing maximum 5 clusters. E: K-means cluster analysis of magnetic and both resistance data allowing maximum 6 clusters. F: K-means cluster analysis of magnetic and both resistance data allowing maximum 7 clusters.

Maximum likelihood (supervised) classification is able to roughly classify some strongly differing classes of features. This classification has relatively pleasing results, when small amorphous anomalies are not considered. These are problematic because they do not have background values while a human interpreter would classify them into the background noise. Supervised classification was only shortly tested, but shows promising results with a minimal input. However, it could not be fully developed due to time and research constraints. The quality of classification largely depends however on the uniqueness of the assigned signature. It is very advantageous, however, that the nature and statistical distribution of the chosen training areas are included and thus some kind of automated geophysical and archaeological interpretation becomes possible, while requiring only a minimal human input. Since too few datasets were available, this classification could not be done with optimal results. To this end more geophysical and other remotely sensed datasets have to be collected and integrated.

Conclusion

The higher resolution magnetic surveys of the central town area considered here have revealed sharply defined archaeological structures throughout the prospection zone, with the exception of the temple *temenos*. The electrical resistance survey results are less clear with depth due to variations in the soil matrix and its compaction and aridity. Nevertheless, the earth resistance data have additional archaeological value, revealing information on fillings of archaeological structures which are magnetically similar to the soil. As a variance is obvious between both datasets, their integration could enhance our understanding of the buried remains.

The geophysical data also clearly illustrate that geophysical data of a Roman urban site cannot be considered as a fixed image of the subsurface, showing only a single period of an archaeological structure. Anthropogenic and natural developments throughout the occupation period are typical to an archaeological site and can heavily change the functioning and lay-out of the original structures. Post-depositional processes have in their turn an important influence on the visibility and interpretability of the archaeological features in the geophysical data. Nevertheless, the obtained data and interpretations confirmed and refined the image we have of the forum of *Ammaia* and its important neighbouring *insula* with bathhouse and probable private *domus*, adding also information about possible preservation conditions of floors and other structures.

The experimental analyses of geophysical data combination techniques applicable to *Ammaia* suggest that qualitative interpretations can be improved through their graphical integration, using an overlay of greyscale and 3D model to visualise a pair of 2 dimensional, respectively trendless and low frequency changing dataset. If 3 datasets have to be visually integrated, orthogonal colour composites, e.g. using the RGB colour model, can be advised. Quantitative data integrations methods using simple mathematical operations such as a weighted difference between resistance and magnetic data can enhance the visibility of the anomalies, while staying easily interpretable. Principal component analysis has the ability to reduce multi-parameter dimensionality and maximise the variation but decreases interpretability. K-means cluster analysis on the other hand has the ability of speeding up the graphical interpretation and classification of large geophysical datasets. Finally, maximum likelihood classification shows promising results, possibly allowing graphical, geophysical and archaeological interpretations of various geophysical and other datasets.

II.5.F EXTRAMURAL MAGNETIC SURVEY

C. Meyer, R. Plesničar, D. Pilz

Introduction – General view on the geomagnetic survey of the extramural area

In two field campaigns in the years 2010 and 2011 a geomagnetic survey was carried out to investigate the surrounding area of *Ammaia*. The objective of the investigation was to prove the extramural extension of the city as well as to find evidence of the city wall and roads leading towards the city gates and of other important suburban structures (see Fig. 65). Compared to the "intramural survey" the objective was not a total coverage of a defined area but rather an attempt to achieve representative data sets of prominently located areas outside the city wall. The terms "intramural" and "extramural" are to be understood as a means to differentiate between the intensive survey of the presumed

Site		***Ammaia* and surrounding area**
Date of fieldwork	2010	4th to 8th of November, 2010
	2011	27th of June to 1st of July, 2011
Field operators	2010	Cornelius Meyer, Dana Pilz
	2011	Cornelius Meyer, Dana Pilz, Rok Plesnicar, Oscar Telschow
Country/ Region/ Subregion/ Municipality		Portugal/ Alentejo/ Alto Alentejo/ Marvão
Coordinate system		UTM 29 WGS84 and ETRS89 / Portugal TM06
GPS-Survey		eastern atlas – Novatel antenna
Visible archaeological structures		Walls, city gate (*Porta Sul*)
Terrain	2010	Areas A/E/H/: slopes and undulated
		Areas B/C/D/F/G/I/J: mainly flat
	2011	Areas M/O/U/V: slopes and undulated
		Areas L/N/P/Q/R/S/T: mainly flat
Land use and vegetation	2010	Areas A/B: olive grove, grassland
		Areas D/G/H/J: ploughed and harrowed field
		Areas C/E/F: grassland
		Areas I: grassland, vegetable garden
	2011	Areas L/M/N/O/Q/R: grassland
		Area P: harvested field, former olive grove
		Area S: harvested field
		Area T: waste land
		Areas U/V: grassland in orchard
Weather	2010	ca. 15-23°C, mainly bright and sunny
	2011	ca. 29-33°C, mainly clear and sunny
Disturbances		Fences, irrigation systems, trees, bushes, modern walls and houses, power poles, pipelines

Table 1. General data of the extramural magnetic survey.

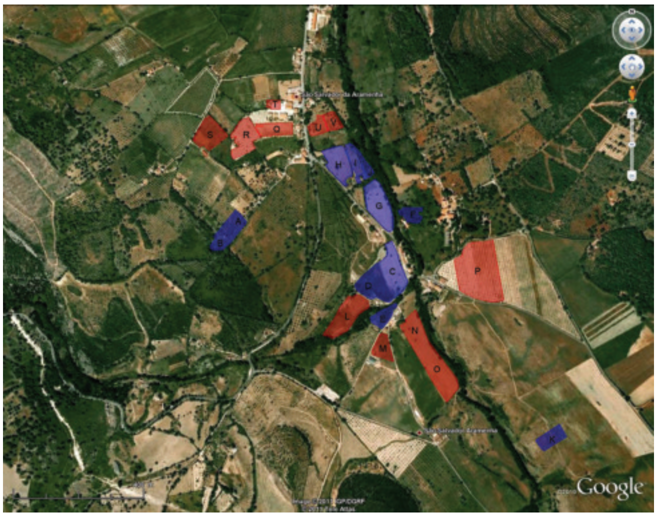

Fig. 65 Location of the extramural survey areas.

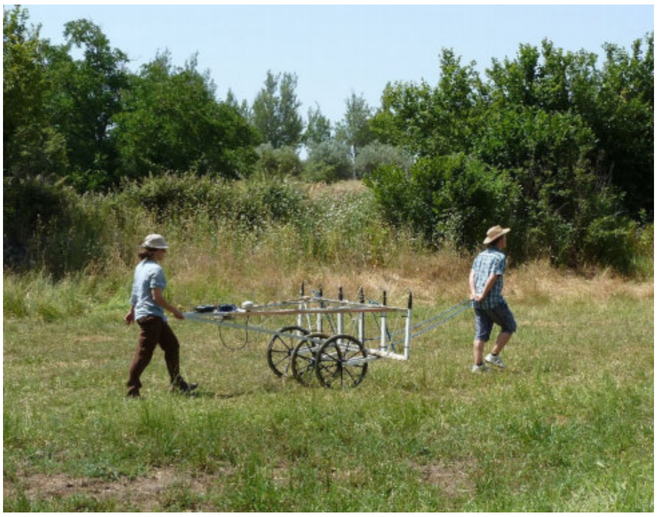

Fig. 66 LEA MAX survey cart with 6 fluxgate gradiometers and 50cm sensor distance.

urban area inside the city wall and the extensive survey of the suburban zone, notwithstanding, that the exact perimeter of the city wall was not known at the outset. Fieldwork was realized in November 2010 and June/July 2011. A summary of the general data of the geophysical prospection campaigns is listed in Table 1.

The investigated areas are situated in the area surrounding *Ammaia* and subdivided into 18 subareas in the north, the south and the east of the Roman city (area A to V, see Fig. 65). Due to the dense vegetations the slope to the West was not accessible for geomagnetic measurements. The investigated areas are located inside a radius of 500m around the assumed or outcropping city wall. In particular, the survey focused on the areas along the western riverbank of the river Sever.

Methodology of the geomagnetic survey

Geomagnetic anomalies are caused by changes in the complex magnetic properties of the soil. The amplitude of the magnetic anomalies is determined by the contrast of magnetic susceptibility between archaeological structure and surrounding uninfluenced soil, as well as volume and depth of the magnetic structure (see sections II.5.a and II.5.b).

In the case of *Ammaia* and its surroundings the varying geological conditions (see chapter II.1) indicated complex magnetic properties of both the archaeological features and the natural underground. Thus, in the magnetic data different amplitude levels and manifestations of archaeological structures were expected.

The objective of the magnetic mapping in the suburban areas of *Ammaia* was the investigation of accessible areas of different size. Since terrain conditions vary from almost even and unobstructed areas to steep slopes a flexible and efficient instrumentation was necessary. In order to meet both conditions, first, the investigation of large areas in short time and second, the adaptability to variable terrain conditions a wheeled array consisting of 6 Foerster fluxgate gradiometers was used (see Fig. 66). The gradiometer probes register the vertical gradient of the vertical component of the Earth's magnetic field with an accuracy of 0.1 nT (Nanotesla). The measured gradient (the difference between two vertically arranged sensors in a gradiometer probe) is insensitive to the typical large fluctuations of the Earth's magnetic field and is determined only by the magnetization of local anomalies in the ground. The high accuracy of 0.1 nT was guaranteed by the application of the high-resolving digitizer LEA D2, specially designed for archaeological prospection. The gradiometer cart was additionally equipped with a GPS receiver novAtel SMART-V1G. Combined both with the distance data recorded by a survey wheel on all meaured profiles and the coordinates of fixed points at the edges of the area a positioning precision of 0.2m was attained. The altitude (Z) data from the GPS could be used to check general topographic features, but was not precise enough to create Digital Terrain Models of sufficient quality.

The technical details concerning the investigation are specified in Table 2. The images of the magnetic data are available in UTM29/WGS84 and ETRS89/Portugal TM06 projection. Furthermore the raw data is there as ASCII files in UTM29/WGS84 projection.

Results of the geomagnetic survey

Approach to the archaeo-geophysical interpretation

When interpreting the magnetic data the variable terrain conditions and the manifold types of the expected archaeological

Method	Geomagnetic prospection
System	LEA MAX
Sensors	6 x Förster Fluxgate Gradiometer FEREX CON400
Vertical sensor separation	0.4m
Sensor height over ground	0.4m
Horizontal probe separation	0.5m
Measuring point distance	ca. 0.05m
Data logger	Digitiser LEA D2 (10 channels), (manufactured by eastern atlas)
Measured variable	Vertical gradient in nT
Configuration	6 sensors, mounted on cart (manufactured by eastern atlas)
Investigated area	ca. 12ha
Processing tool	Decoding program including offset and drift correction
Distance measurement	Odometer (survey wheel), GPS NovAtel SMART-V1G
Data format	ASCII, GeoTiff UTM29/WGS84, GeoTiff ETRS89/Portugal TM06
Image resolution	0.25m x 0.25m

Table 2 Technical specifications of the extramural magnetic survey.

structures had to be taken in account. In particular, it was expected that similar archaeological structures can manifest in magnetic anomalies of variable amplitudes and characteristics depending on different construction material of walls, on the geological substratum and the alluvial sedimentation.

The most functional tool for the interpretation of magnetic data is using GIS. In the case of the extramural survey of *Ammaia* we used the open-source system QuantumGIS (www.qgis.org). The first step in producing the interpretation was the delimitation of magnetic anomalies by polygons in order to determine their extension and their main orientations. The second step was to classify the delimited anomalies according to their magnetisation in positive, negative and dipole-like (bipolar) ones. Inside these classes a further, more detailed differentiation considering their amplitudes was undertaken. Anomalies with amplitudes of more than 20 nT were classed as “stronger anomalies”, correspondingly anomalies with amplitudes of less than 20 nT were considered as “weaker anomalies”. Following this scheme all considered magnetic anomalies (total number: 425) were differentiated in six classes. Further 436 magnetic anomalies were already left aside because of their presumed non-archaeological character. In particular, the attribution of classes resulted in the following breakdown:

1. Anomalies of weak positive magnetisation: 183 individual anomalies,
2. Anomalies of strong positive magnetisation: 68 individual anomalies,
3. Anomalies of weak negative magnetisation: 124 individual anomalies,
4. Anomalies of strong negative magnetisation: 28 individual anomalies,
5. Anomalies of weak bipolar magnetisation: 1 individual anomaly,
6. Anomalies of strong bipolar magnetisation: 21 individual anomalies.

The relative low density (ca. 72/ha) and the lack of manifold superpositions of magnetic anomalies in the suburban areas compared to the very complex data from the intramural survey allowed a further step of differentiation. The individual anomalies were analysed in respect of their origin. An attempt was made to distinguish anomalies of geological or archaeological origin and disturbances of the magnetic data caused by modern structures like scrap metal, fences, poles and pipelines. Structures that were identified as archaeologically relevant were classified by their dimension, magnetic value and shape, resulting in six categories (walls, roads, ditches, pits, pavements and fireplaces). All structures that could not be reliably associated with one of these categories were indicated as “undefined”. That means that an archaeological origin is likely but no functional or structural context was recognized.

The association of the magnetic anomalies to archaeological structures followed some general rules. Circular and oval-shaped anomalies of weak positive magnetisation are generally considered as footprints of pits. If the positive magnetisation is stronger furnaces and fireplaces can be expected. Linear positive anomalies can be associated with fillings of ditches, foundation trenches or road pavements. Negative anomalies, in most of the cases as linear structures, indicate remains of walls and foundations. Their amplitudes give hints to both the thickness of the top soil and the state of preservation of the architectural remains. Extensive, randomly-shaped anomalies of both weak nega-

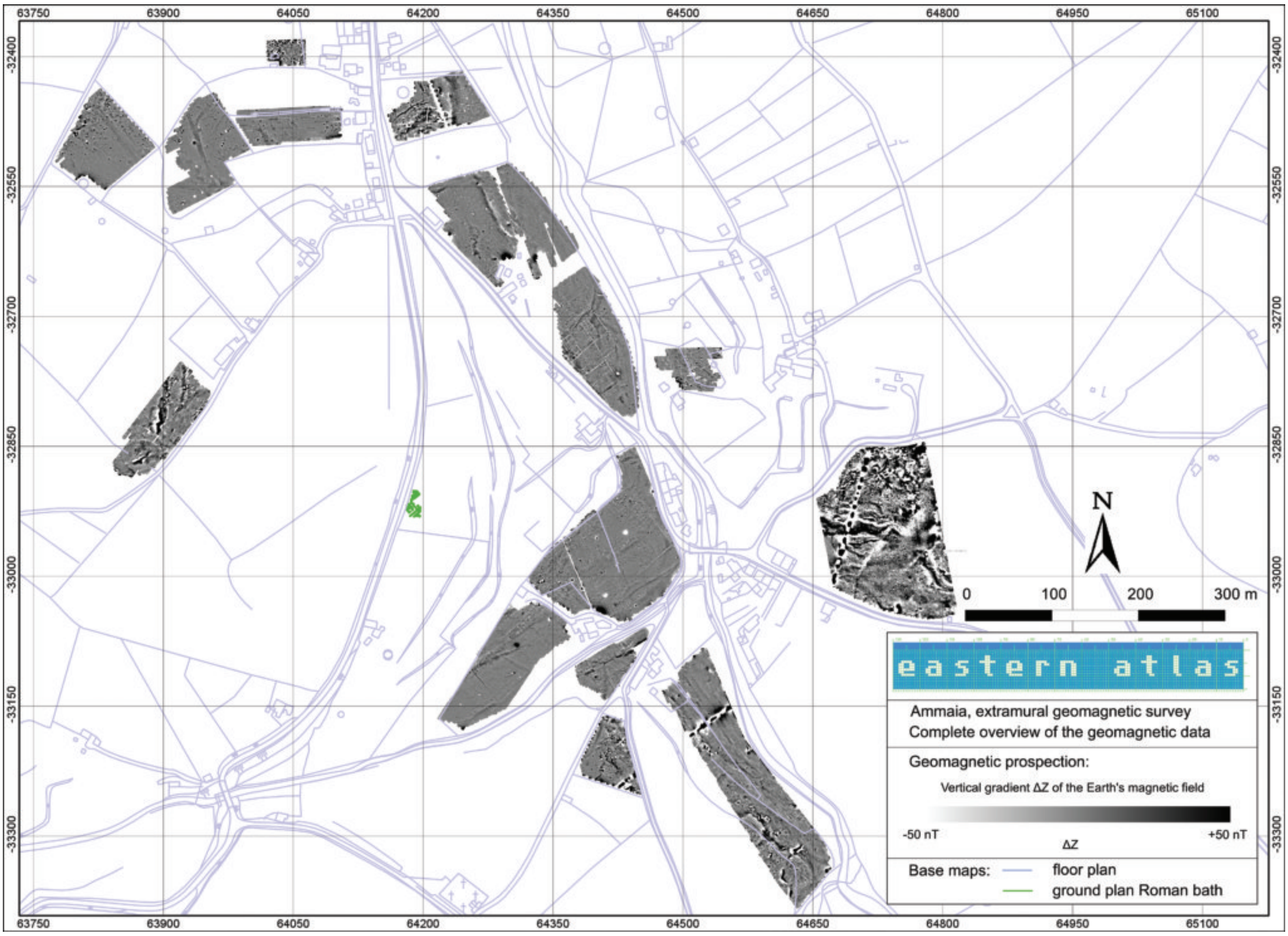

Fig. 67 Overview of the geomagnetic data in the extramural area.

tive and positive magnetisation in association with wall structures can be indications of pavements inside of buildings. Bipolar anomalies of lower and medium amplitudes can be ascribed to structures with strong thermo-remanent magnetisation, i.e. furnaces and fireplaces. All attributions of magnetic anomalies had to be revised individually in respect of the plausibility of the archaeological interpretation. In particular, this involves the exclusion of a possible modern or natural origin of the anomalies and the validation of the structural context with other magnetic anomalies (Mommsen 1986). This resulted in the following classes and numbers of individual elements:

1. Walls, foundations: 118 elements
2. Roads: 24 elements
3. Ditches, foundation trenches: 13 elements
4. Pit fillings: 103 elements
5. Pavements: 25 elements
6. Fireplaces, furnaces: 21 elements
7. Undefinable anomalies: 121 elements

The magnetic anomalies of non-archaeological origin were subclassified into the two categories of natural and anthropogenic structures. The former were associated with metal objects, gullies, garbage disposals, pipelines, above-ground obstacles and agricultural structures like tree pits, the latter are attributed to either bed-rock formations or lightning-induced magnetic anomalies. The origin of another large group of anomalies could not be determined in detail. The total number of considered non-archaeological anomalies was 436.

According to this interpretation scheme several anomaly clusters could be identified as functional areas like building complexes and a necropolis. The details of the archaeological interpretation are presented in the following paragraphs. All chosen attributes associated with the magnetic anomalies are summarised in the GIS data base. This data base is to be considered as work in progress in such a way that additions and modifications are possible when new results of direct or non-destructive investigations lead to a better understanding of the patterns of the magnetic anomalies.

In the following the specifications of the interpretation of all investigated areas are addressed. Archaeological features as well as natural characteristics of the investigated areas are presented with due regard to the influence of modern anthropogenic structures to the magnetic data. The areas are arranged according to their location in three groups.

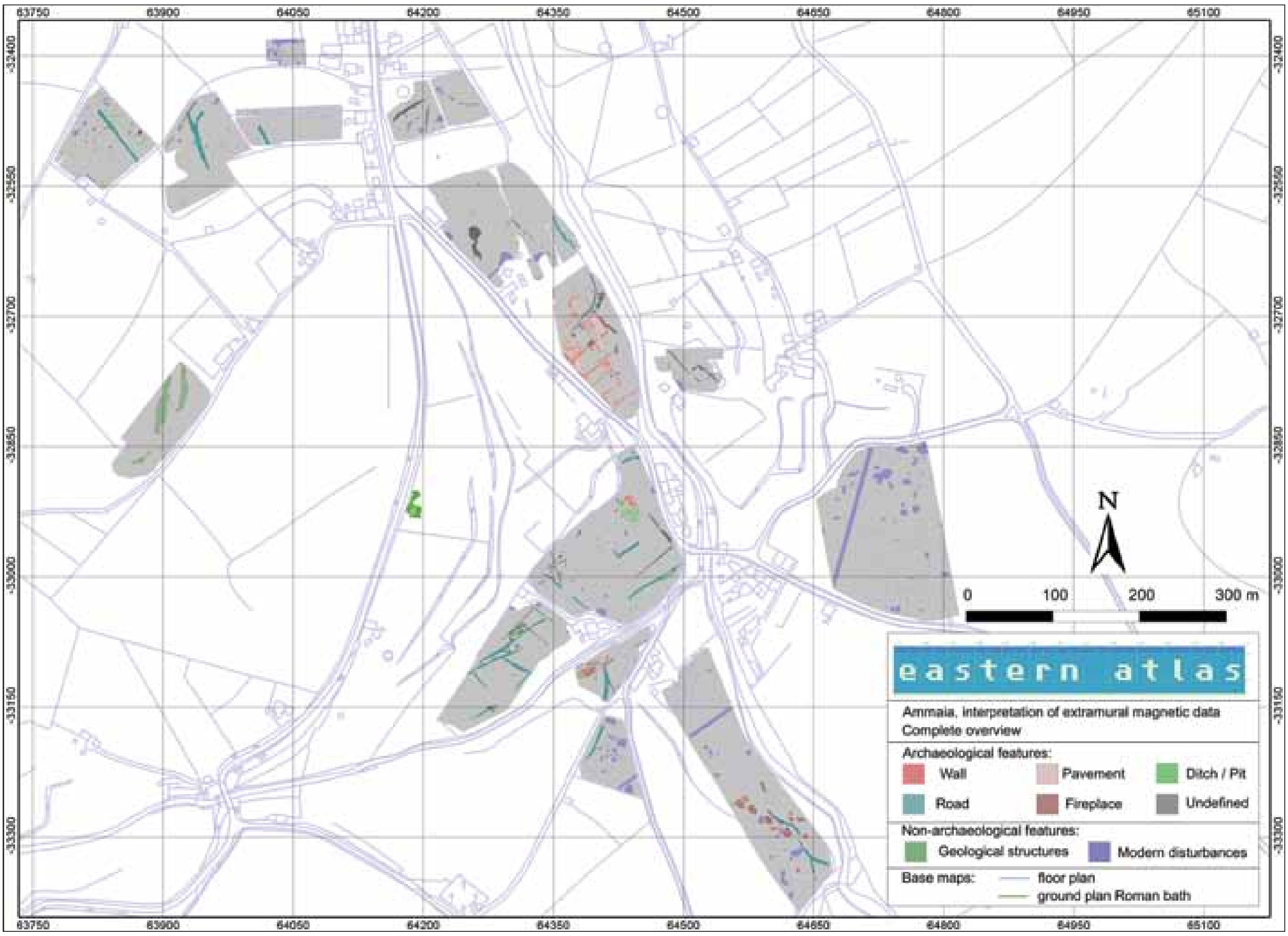

Fig. 68 Overview of the archaeological interpretation in the extramural area.

Northern suburbia (areas A, B and Q to V)

The description of the individual investigation areas is given in clockwise direction from NW to NE. Except for the olive grove in area A all northern areas were open spaces with only few trees and bushes.

The areas A and B are located along the supposed perimeter of the north-western city wall. Their topography is steep in the lower part and flat in the upper part, where a suspicious, approximately semicircular niche (diameter ca. 40m) in the rock formation was included in the investigated area. The registered magnetic data is dominated by strong magnetic anomalies mainly referring to the quartzite and schist formations in the ground (Vermeulen *et al.* 2005) indicating a very thin top soil layer. Clear evidence of archaeological structures is not recognisable. Neither in the flat area on top of the slope nor in the slope itself signs of archaeological structures are visible. An explanation for the lack of archaeological structures in the data can be found in extensive erosion processes at the slope. However, the flat area on top of the slope indicates a quarry of uncertain dating.

Area S is smoothly sloping to the NE. It is situated approx. 250m NW of the supposed city wall. The most striking structure in this area is a SE-NW running linear structure associated with a road pavement. This archaeological interpretation is supported by groups of magnetic anomalies caused by pit fillings and fireplaces clustering on both sides of the linear structure. This combination of structures suggests that the remains of an ancient suburban production centre can be expected in the ground. Due to the limitations of the area by pathways, fences and cultivated areas the total dimension of the production centre remains unclear.

Furher to the east the three areas Q, R and T form a nearly coherent surface situated very close to the village of São Salvador da Aramenha. The proximity of the modern village resulted in a higher density of non-archaeological magnetic anomalies, mainly caused by scrap metal and garbage disposals. Nevertheless, the western part of the area, in particular area R, shows clear evidence of a Roman road heading NW with a bifurcation leading to the NE. The main road corresponds with the urban street grid of *Ammaia* in a way that it obviously leads in the presumed principal *cardo* of *Ammaia* at a still hypothetical northern gate of the Roman city.

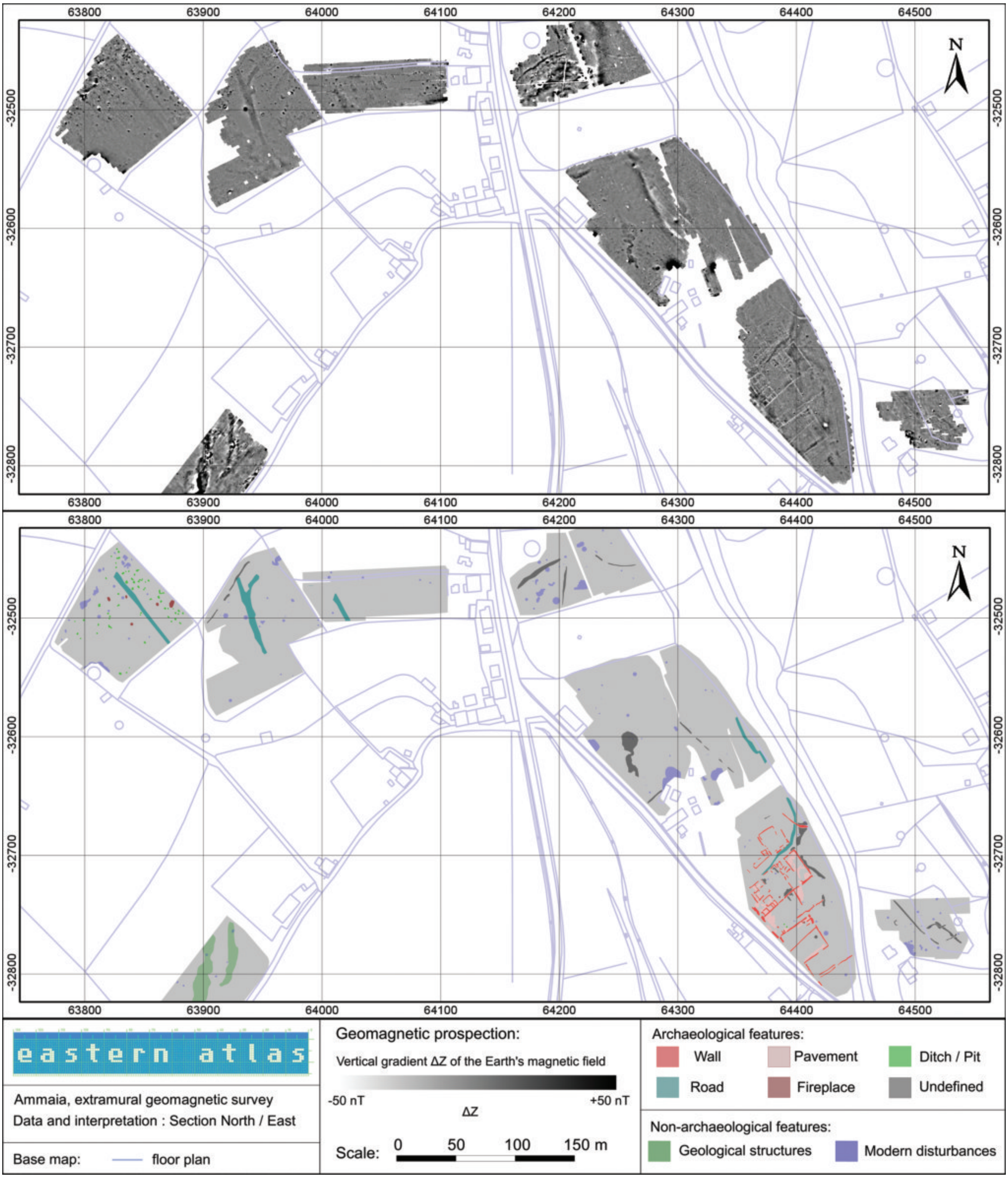

Fig. 69a Section north and east, geomagnetic survey data and archaeological interpretation.

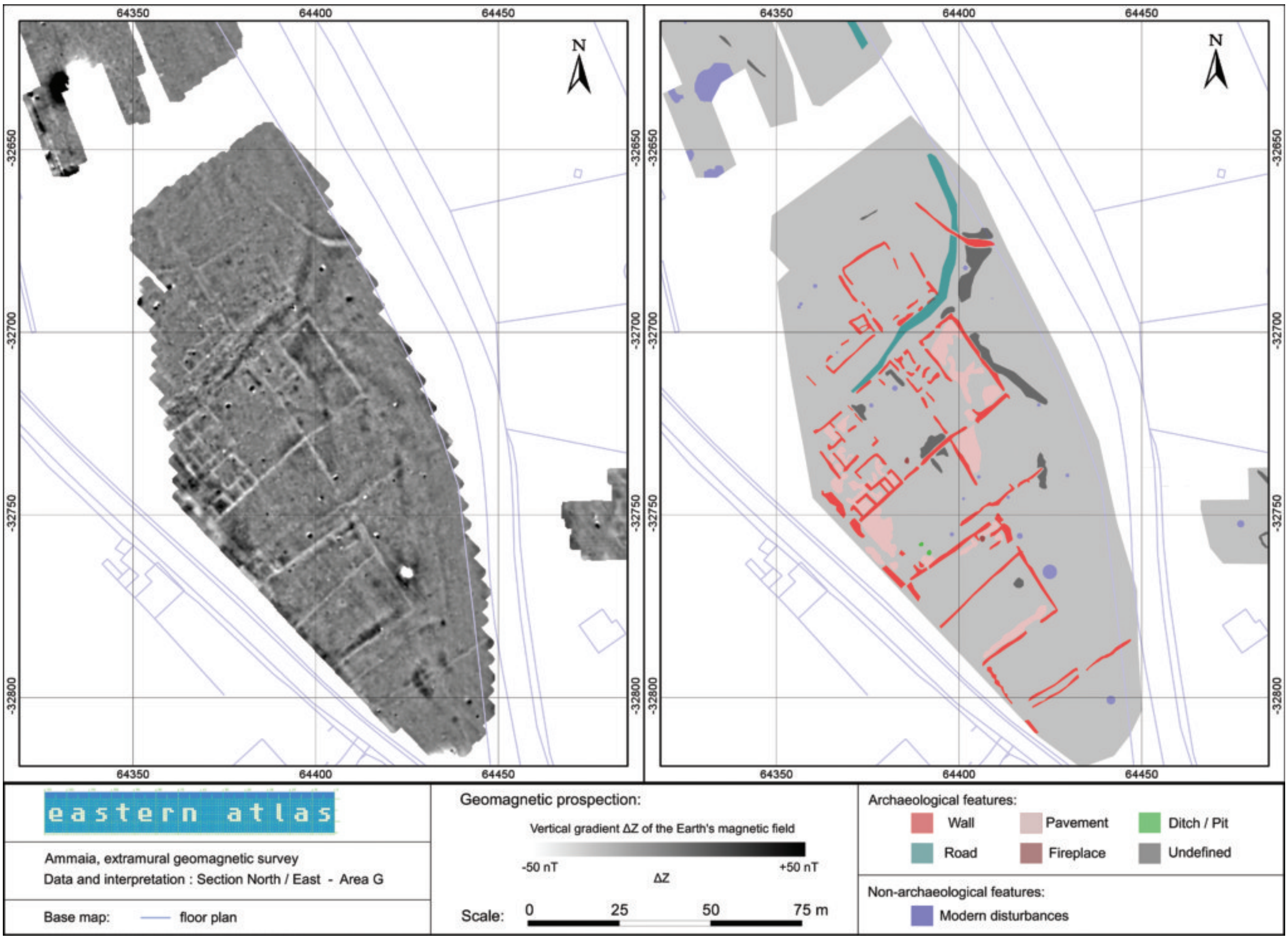

Fig. 69b Section east, Area G, geomagnetic survey data and archaeological interpretation.

The areas U and V are located beyond the road N359 on the slopes to the river Sever. Due to the use of these areas as fenced orchards and goat pastures there is a considerably high influence of magnetic anomalies of modern origin in the data. For this reason no clear archaeological features are delimitable. Furthermore, the interpretation of the data was complicated due to the inhomogeneous characteristics of the top soil layer on the eroded slopes. Several anomalies were associated with aboveground metal objects, but the attribution of the majority of the magnetic anomalies remains undefined.

The Western riverbank of River Sever (areas G to J)

The investigated areas H, I and J are located approx. 100m south of the areas U and V along the assumed north-eastern section of the city wall of *Ammaia*. The dominating magnetic structures of area H are most likely of modern or geological origin. In the southern sector big amounts of iron (tubes and poles) caused very strong magnetic anomalies. In the centre a circular, weak positive anomaly corresponds to a accumulation of stones covered by grass. It is connected with an irregularly shaped positive anomaly reaching approx. 20m to the south. Its origin could be a refilled quarry of uncertain dating.

The two areas I and J are characterised by very homogeneous magnetic data with only sparse weak anomalies. Circular anomalies in the northern sector are caused by ruts, smooth anomalies in the eastern part display geological and topographical features reflecting buried riverbanks of the river Sever. Only a linear, 60m long and negative anomaly might be of archaeological interest. It corresponds with a similarly orientated negative anomaly located in area G and runs from NW to SE. Possibly this structure indicates a water drainage of uncertain dating.

Area G adjoins the areas I and J to the south and is located opposite the museum along the southern part of the north-eastern section of the city wall. It is about 1 ha in size. The surface was ploughed and harrowed. Nearly the entire site is dominated by linear negative anomalies clearly displaying extensive building and road structures. The orientation of the anomalies is approximately parallel in relation to the supposed north-eastern city wall and the excavated structures in the surroundings of the museum. In the northern part of the area an 8 to 9m wide road or path runs from the city towards the river Sever. In the central part of the building complex even compartments of the principal buildings and paved floors were recognised. The building complex is likely one of the key areas for the understanding of the functioning of the city, particularly regarding the interrelation of city and river. The area was also object of detailed investigations like coring and artefact collection surveys (see chapters II.1 and II.5).

Beyond River Sever (areas F and P)

On the eastern riverbank only two areas were investigated by magnetic measurements. Area F is a comparatively small (0.27ha), but highly contaminated site. Several modern structures like buildings of the mill complex, walls and garbage are located on the site. An elongate negative and linear anomaly running from NW to SE is of uncertain origin but most likely refers to a water conduit or a foundation related to the mill complex. Several randomly scattered small positive and oval-shaped anomalies most probably correspond with fillings of pits of unknown dating.

The extensive area P (1.3ha) is located on a higher terrace of the river, 200m SE of the mill complex (today housing the administration of the Nature Park of the Serra de São Mamede). At the time of the measurements the area was a stubble field but a large number of regularly arranged negative anomalies prove that the area used to be an olive grove. The dot-shaped negative anomalies still reflect the refilled tree pits. Satellite images from 2009 still show the regular grid of an olive grove. However, the small anomalies of the tree pits are interfered by strong bipolar anomalies caused by the Devonian dolostones and schists close to the surface (Vermeulen *et al.* 2005). The suspicious gap in the geological structures in the centre of the area indicates an intensive levelling of the area in recent times. Additionally anomalies from a pipeline crossing the area and from local garbage deposits influence the magnetic data. Even a lightning-induced anomaly could be located in the northern part of the area (Jones and Maki 2005). Despite all that no archaeological evidence could be recognised in the magnetic data. The recent serious alterations of the area are probably responsible for the complete disappearing of possible archaeological traces.

The triangle between Porta Sul and the stream (areas C, D and L)

Adjoined to the south-eastern section of the city wall and covering the area between the city wall in the north and a tributary of river Sever in the south a surface of approx. 3ha was investigated. The three areas C, D and L are characterised by disturbing anomalies from wire fences, power poles and irrigation systems. Even so several structures of archaeological interest are identifiable in the magnetic data. On area C, close to the south-eastern corner of the city wall a group of linear positive anomalies in a rectangular grid display building structures covering an area of approx. 900m². The weak positive anomalies suggest that there are no preserved walls and foundations but only filled foundation trenches in the ground. The orientation of the longitudinal axis of the building complex is approx. NW-SE.

Due to the intensive agricultural activities in area C it is difficult to determine the origin of several linear anomalies. Weak NNW-SSE striking anomalies refer to plough marks meanwhile a elongate negative anomaly running from the SW to the NE reflects most probably a water conduit of the irrigation system.

Area D is closely connected with the *Porta Sul* and covers its suburban foreland. There is surprisingly few indications of archaeological structures in the data. Nevertheless it is possible that a big part of the expected road structures were eroded by agricultural works and therefore not visible in the data.

Further to the west area L completes the triangle between the city wall and the tributary stream. Several linear positive anomalies with different orientations cross the area. Their origin remains unclear. Besides traces of natural water courses remains of pathways and historical field boundaries are conceivable. However, in the northern part of the area a group of linear and circular-shaped anomalies indicates building structures connected with a road running from the NE to the SW in direction of the southern corner of the city wall.

The south-east – up the river Sever (areas E and M to O)

On the southern bank of the tributary two smaller areas with a total surface of approx. 0.5ha (area E and M) were investigated. Further to the south, along the western bank of river Sever a large area of a size of approx. 2.8ha was added.

The undulating surface of area E makes the interpretation difficult. In spite of this complication and the limited area some structures possibly associated with a small-scale building complex were located. These structures are arranged along the southern bank of the stream and are adjoined by perpendicular structures indicating pathways or roads in southern direction. Uphill in short distance to the south the magnetic data of area M shows likewise indications of a road structure running in south-western direction. Beside extensive magnetic anomalies caused by disposals and installations of the close farmstead accumulations of positive circular anomalies point to a large number of pit fillings. Comparable with the structures in the northern suburbia (area S) another production centre located along a road can be expected. The proximity of the water supplies and the good accessibility for the supply of primary materials support this assumption.

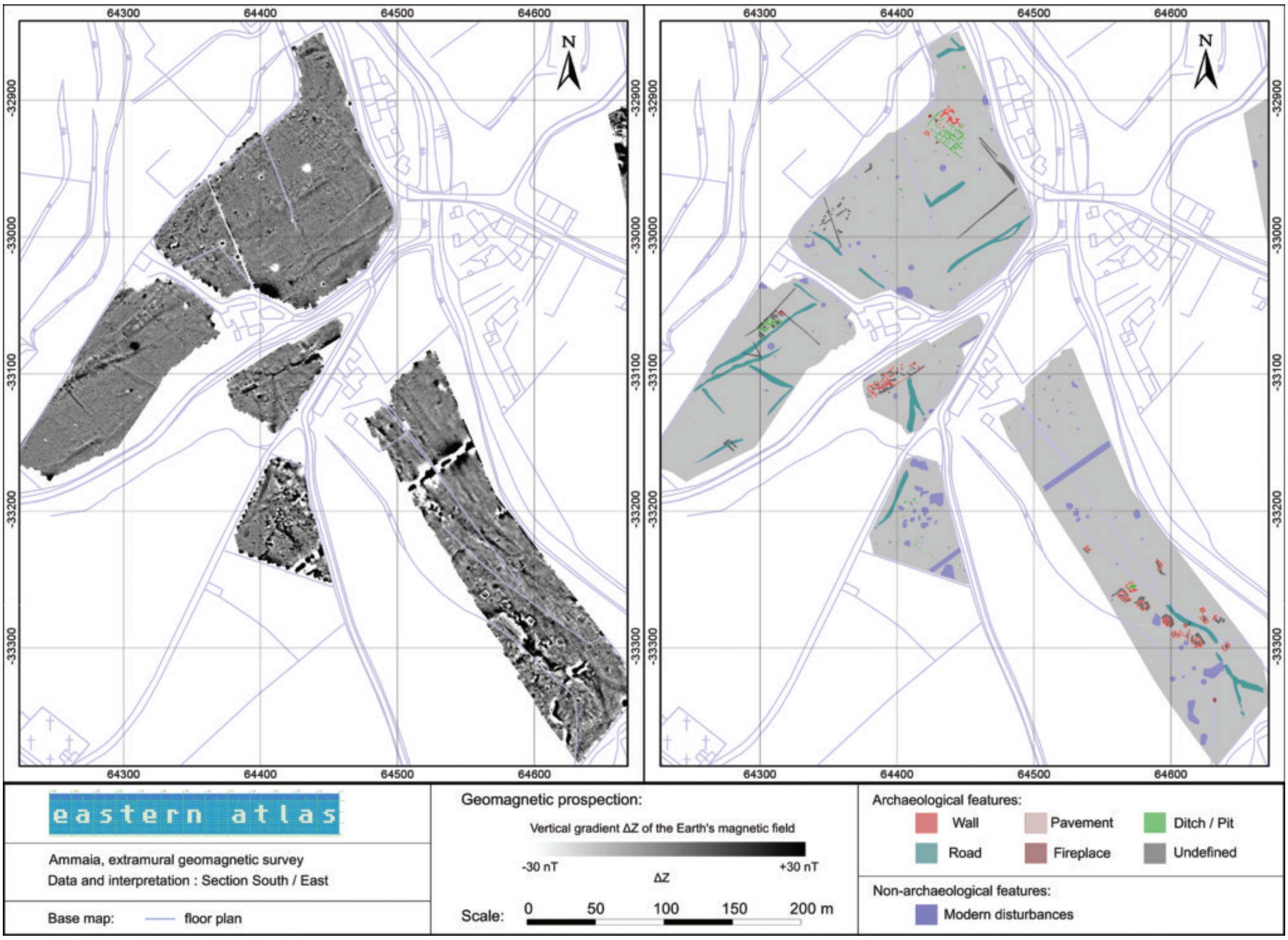

Fig. 70a Section south, geomagnetic survey data and archaeological interpretation.

Another road, possibly the principal road in southern direction from *Ammaia* was located in the areas N and W, parallel to the river Sever. Due to the variable thickness of the alluvial sediments in the areas close to the river the road structures are only partially visible in the data. Additionally, a pipeline crossing the area complicates the interpretation. But the hypothesis of a principal road is supported by the existence of clear magnetic anomalies indicating architectural remains in the ground with the typical dimensions of Roman funerary monuments. The traces of at least 15 individual tombs are recognisable. Their arrangement along the assumed principal road in a distance of approx. 400m from the southern city gate (*Porta Sul*) allows the conclusion that a part of one of the principal necropolis of *Ammaia* was discovered by the magnetic survey.

Summary and outlook

The results of the extramural magnetic survey proved the efficiency and practicability of geophysical prospection methods for investigations of ancient urban landscapes. In two short field campaigns of one week each a representative section of *Ammaia*'s suburbia was studied. The total investigated area had a surface of approx. 12ha. In spite of limited accessibility of cultivated land and recent terrain alterations several suburban features of high archaeological interest were detected. In particular, the following principal elements of the suburban landscape obtained from the magnetic data were located:

1. In the north of *Ammaia*: In a distance of approx. 300m from the north-western section of the city wall a production centre can be expected. The magnetic anomalies indicate a road structure adjoined by pits and furnaces (Area S). This presumed industrial area is located approx. 100m west of a major road structure, very likely reflecting the principal road to the north. The road structure shows a bifurcation, where a branch road obviously leads to the NE.
2. In the eastern suburbs: Along the north-eastern section of the city wall directly opposite the Museum of *Ammaia* an extensive building complex linking the intramural area and the river Sever was discovered (Area G). The magnetic anomalies of the walls and the associated structures like paved floors, pathways

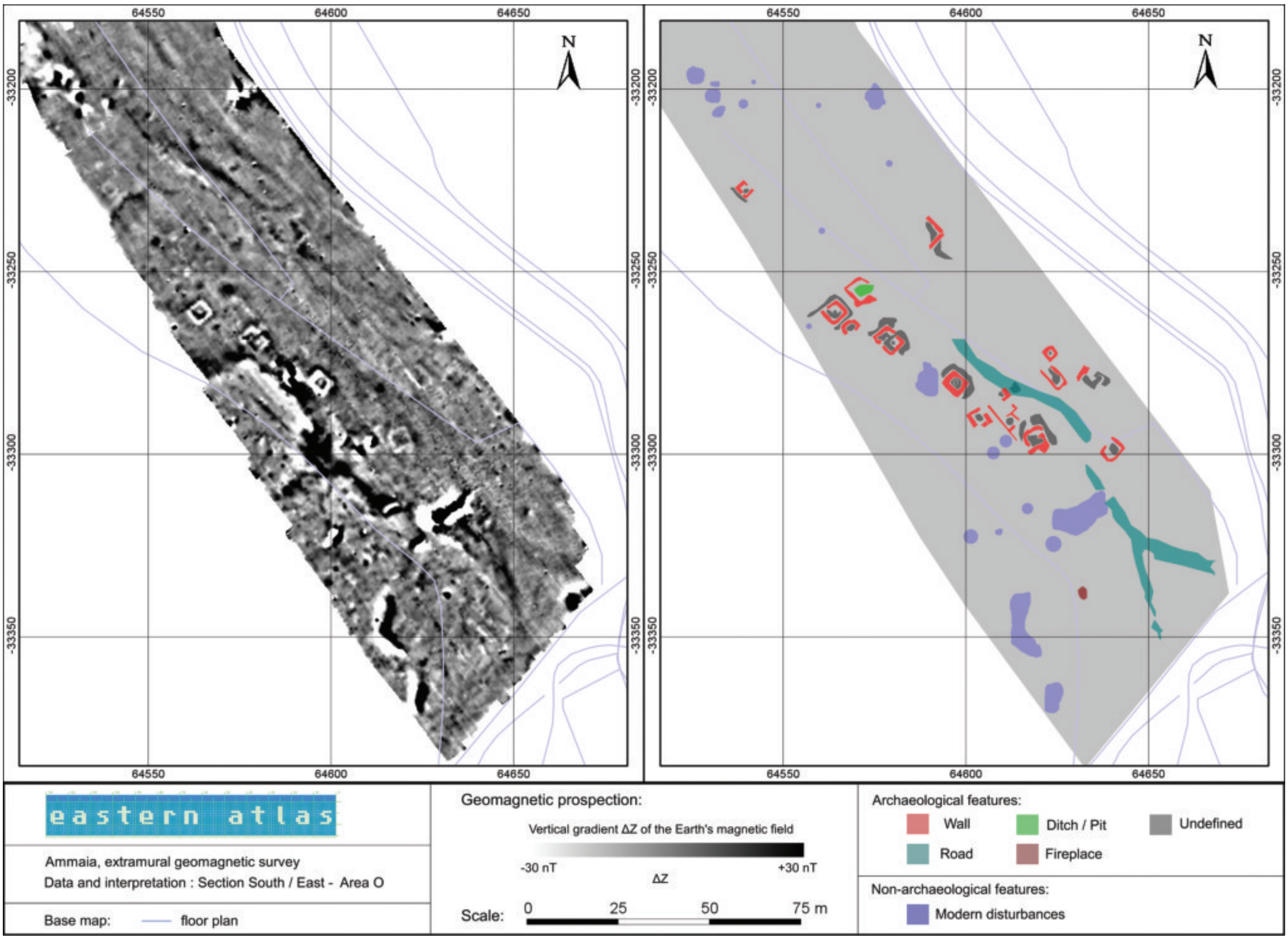

Fig. 70b Section South, Area O, geomagnetic survey data and archaeological interpretation.

and pits indicate a comparatively favourable conservation status. Further detailed information regarding the archaeological remains in area G were obtained by means of geoarchaeological coring (see chapter II.1) and in both extensive and intensive artifact collection surveys (see chapter II.6).

3. In the south: Close to the south-eastern corner of the city wall another building complex was discovered (Area C). The positive anomalies suggest that the foundations were destroyed in large part and only the refilled foundation trenches remained in the ground. In southern direction of *Porta Sul* the magnetic data show only few clear structures, but traces of the principal road heading southeast can be recognised (Area D). Beyond the tributary some minor building structures were detected. Along a road leading to the south-west an accumulation pit structures indicate another production centre (Area M). While the road associated with the production area tends in direction of the southwestern mountains the principal outward road coming from *Porta Sul* leads to the south-east following the river Sever (Areas N and O). In a distance of 400m from *Porta Sul*, on both sides of this main road there is clear evidence of remains of funerary buildings in the ground. It is very likely that one of the principal necropolis of *Ammaia* is buried in the gentle slopes of the western riverbank of the river Sever (Area O).

The spatial organisation of the detected suburban structures of assumed Roman origin corresponds well with the topographic conditions. The two production areas were located along roads leading to the NW and SW where either a convenient water supply was guaranteed or primary materials might have arrived from their sources. Although the function of the detected building complex in the plains between the north-eastern section of the city wall remains still unclear, the area was considered as one of the crucial points of the organisation of the Roman city in relation to the river. Of little surprise is the localisation of an extensive necropolis adjoined to the principal road heading SE. The detected traces of a road pavement reflect probably the ancient road leading to the capital of *Lusitania Emerita Augusta*.

II.5.G SWINGING *AMMAIA*. METAL DETECTING AS A REMOTE SENSING SURVEY TECHNIQUE

A. Bosman

Introduction

In this section we present the results of another non-invasive survey technique applied in *Ammaia*: metal detecting. Although more object orientated than the other techniques, where the aim is the recording of structures, it has its worth in positioning activity areas and can be used as check-up of anomalies registered by the other techniques. The idea of testing this particular remote sensing technique in *Ammaia* was raised at the end of the 2010 campaign, which produced interesting geophysics results in the peripheral areas of the site where modern ploughing produced good quantities of surface material. The systematic use of a metal detector could indicate here the presence of metal objects within specific areas of the suburban and urban landscape. These might indicate concentrations of particular objects and therefore possible activity areas could be identified. The results of the geophysics would be leading in the choice of the areas which are to be researched further. Also the results of coring operations in these zones would be helpful to indicate in which areas there is colluvium which covers the Roman layers or where there might be other disturbances, e.g. erosion or excavation. The aim was that several areas of *Ammaia* should be covered and any signals were not to be excavated, but registered using a total station hopefully resulting in a series of specific concentrations or activity areas. Furthermore, the test with metal detecting on site was also aimed to be included in the Risk Analysis of the site, a part of the Site Management Plan.

Technical data

The metal detector of choice is a White's M6. It operates on a frequency of 14 kHz. This detector type is equipped to be used in remote sensing for it not only indicates the presence of a metal object in the topsoil, but also on the basis of the reading of its conductivity it indicates the type of metal. This type is indicated by a sound in 7 different tones, of which there are two low tones, three medium tones, and two high tones as follows:

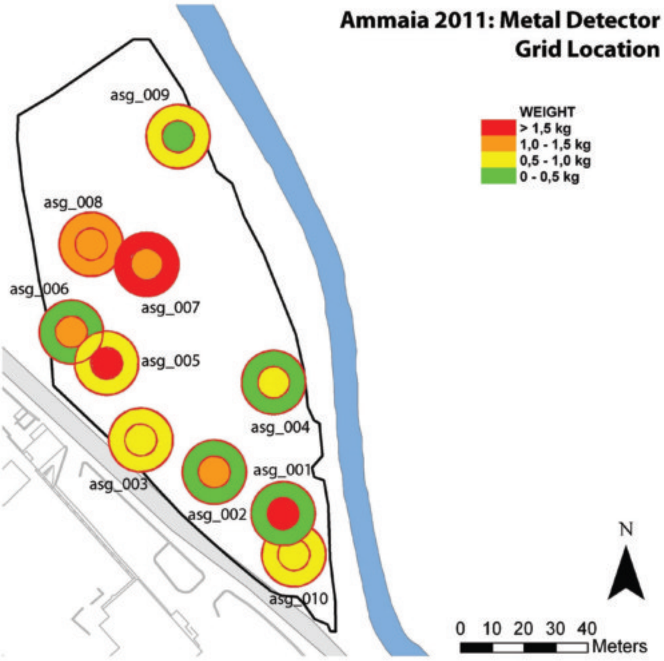

Fig. 71 The field adjacent the museum with 10 and 20m grids (N-S oriented squares shown here as circles) and indication of metal contents in kgs.

-95	= 57 Hz	(Very Low)	Hot Rock
-94 to -6	= 128 Hz	(Low)	Iron
-5 to 7	= 145 Hz	(Medium Low)	(Gold) – Foil
8 to 26	= 182 Hz	(Medium)	(Gold) – Small Pull Tabs
27 to 49	= 259 Hz	(Medium High)	(Gold) – Large Pull Tabs
50 to 70	= 411 Hz	(High)	Copper – Screw Caps
71 to 95	= 900 Hz	(Very High)	Copper – Silver

On the digital display a VDI (Visual Discriminator) is shown where a metal type is indicated (e.g. 'iron' or 'foil') and a number to mark its conductivity. Negative numbers are usually associated with iron. These numbers are also accompanied with a bar whose position on the scale from left to right is an indication of higher or lower conductivity. The sound when iron is found is a low grunting one, while the pitch is higher for other metals, the highest possible being silver.

Another feature which is essential when non-invasive archaeological research is carried out, is the pinpoint capability of this detector. Any metal object can be located in a more precise manner by using the pinpoint switch. The sound increases when the object is in the centre under the coil. Using this technique the digital display marks the depth within the topsoil up to a maximum of 12 inches. As such the range within the topsoil is officially limited to this depth although under ideal conditions larger objects may be detected on even deeper levels. The rocky topsoil in *Ammaia* was expected to have an extra diminishing effect on the range of the detector, for stones might obliterate the otherwise detectable disturbances in the magnetic field as developed by the detector. Also magnetic capability of certain types of rock may produce certain signals and therefore distort the observations. Another element of importance is the way in which a site is overgrown. High vegetation hinders a proper use of the detector for the disk should be as near to the surface as possible.

The detector employed was fitted with a wired cord and small plug addition to fit a walkman/IPod headset, to avoid being burdened with a heavy and warm normal headset. The use of a headset is advisory as faint sounds could be missed. Experience taught that especially objects in a deeper position or covered by rock can only be detected this way.

The first tests

The field survey with metal detector was carried out in *Ammaia* during one week of July 2011. The metal detector was first tested on the premises of the archaeological park at *Ammaia,* therefore in the intra-mural area of the urban site. Both old spoil heaps of the excavations and the surface in the near vicinity of the monuments were chosen. Also the mown surface was tested around the museum building and the first terrace west of this and the laboratory. Both resulted in a series of metal finds. The VDI indicator worked as expected. It was noted that objects of lead could be indicated in a wide range from iron up to a conductivity of +38, a higher pitch of sound suggesting another metal than iron. Another feature which developed more strongly during the day by solar heating of the soil is the increase of indications of ‘Hot Rock’. This could be explained by the high iron content of most of the stones at *Ammaia*, which seem to react when heated. The sound is similar to iron, but a fraction lower and interrupted. It was noted that the pinpoint depth indication differed from the spoil heaps to the surface test. This is probably due to the more loose content of these heaps, in which the metals were unable to form a corrosion mark or shadow in the soil.

As this was a test to determine the capacity of the detector, the objects were recovered. This resulted in a wide range of all metals, both modern and of Roman times. Most of the older objects can best be described as scrap and molten parts, indicators of melting of iron, lead and copper or bronze. In addition to these also two coins were discovered. Both are fourth century AD *Aes*.

The baths

Before being employed as a research means on its own the metal detector was used to assist at both excavations in progress. First the spoil heaps at the baths were investigated. Here the different layers and contexts were separately dumped. Therefore, any finds could be associated with their original position. Parts of these spoil heaps were the result of sieving the ground. As was to be expected no metal finds were recovered here. The maze of the sieve (ca. 4mm) is fine enough to retrieve the smallest metal objects. Sieving also enables to recover even lead fragments, which are difficult to discover between stones of the same colour. This is an element which is of less influence when copper (green) or iron (black to brown) is involved.

In the spoil from an ash layer many fragments of molten lead and bronze, a bronze belt fitting and several shoe nails were discovered. This layer already yielded several metal objects when it was excavated by hand in the trench.

The forum

Near the temple on the forum the excavation area was also investigated in this way. On the spoil heap of the campaign of 2010 a coin (Late Roman *Aes*) was discovered. Also several fragments of lead plate and droplets were found. The lead could be an indication for the presence of a water tank positioned near the steps in front of the temple. The droplets are in that light waste of the soldering of the tank. Another explanation is that the droplets are the remains of clamped building blocks wherein the iron clasps are fixed in position using molten lead.

The metal detector was also employed within trench 1. Here three signals were noted and their positioned marked. They turned out to be two iron nails and a coin (Late Roman *Aes*) when retrieved by the excavators. On the surface excavated in the 2010 campaign two signals were recorded. Both objects were investigated. The first was a lead droplet. At the same position more of this metal is still *in situ* for it is not recovered. It is left for a further excavation campaign because of its depth below the surface. The other recovered object appeared to be a fragment of a bronze plaque. As the forum was the foremost formal area of any city, it is the opportune section where official notices were made public. The medium was usually a bronze plaque with inscription. It is an appealing thought that this fragment was part of such a notice. Unfortunately no inscription of text survived on it.

Following this a survey of the surface around the temple podium was carried out. As this was a non-invasive action no objects were recovered. Several signals were recorded, most of them being iron, although some lead objects are suspected to be present as well. Surprisingly no high conductivity signals were recorded. In the field in between the temple area and the modern road a concentration of lead plate fragments, strips with nail holes and some droplets were discovered. These were retrieved as all of them lay almost on the surface. The concentration may also be an indication for lead sealed waterworks or another building use. Interesting enough these finds do not coincide with an anomaly directly to the west of it in the next field, where a structure associated with a drain or aqueduct is suspected, crossing diagonally the forum square (see section II.5.c and Vermeulen, Corsi and De Dapper 2012).

An attempt was made to locate this anomaly. Across the field where this feature is located several sweeps were made both crossing and parallel to this feature. No traces of a long stretched signal were found. The only signals recorded were of larger iron objects, mainly parts of modern agricultural equipment. All of these lay in a position on or near the surface. Interesting enough no other signals appeared which again gave an impression that the field may have been detected at an earlier stage, leaving only the 'non-interesting' bits.

The extra-mural area between town wall and river Sever (sector ASG)

As it was assumed that the metal detector survey could integrate well with results from geophysical surveys and grid-based artefact surveys, achieved earlier in the arable fields directly east of the walled urban area (section II.5.f and chapter II.6), a first test was carried out on the recently ploughed field opposite to the museum (Fig. 71). According to these geomagnetic surveys here, this terrain was originally situated immediately outside the eastern city gate. The geophysics results showed a road leading from the river to this gate with several dwellings or buildings on both sides. One building seemed associated with the road, while another could have been linked with the monumental tomb excavated in front of the museum building (Pereira 2009). The field was crossed from south to north covering two strips of ca. 1,5m width. These strips were investigated by the White's M6 and the metal detector present at the excavation, a Minelab Sovereign, which operates on an analogue system. Both detectors yielded several finds: apart from some lead and many iron objects three coins were found, of which two Late Roman *Aes* and a twentieth century Portuguese nickel coin. No concentration of finds was noted.

After the first test two days were spent detecting in selected areas of this field within a grid layout located by a total station. The centres of ten squares (each measuring 10m side and numbered ASG 001 to ASG 010) were investigated. First a survey was carried out within the squares by collecting pottery and other distinguishable finds by hand. In square ASG 008 a remarkable amount of pottery, among which *terra sigillata* and amphorae, was noted. Then all squares were detected by using both the White's M6 and the Minelab Sovereign, starting in their centre from 0 – 10m. Thereafter the square was widened and metal was recovered from 10 – 20m as well. This measure was taken to get a grasp of the near vicinity of the grids. All squares were double checked by using the White's M6. This yielded several more finds, mainly of iron, but also other metal-types, e.g. part of a (modern) bronze bell. In five squares no metal seems to have been found. The number of metal finds is in balance with the weight per square, except for the centre of square ASG 007 where a number of 68 finds weighs just ca. 1kg. An overview of the finds and their weight is indicated in the tables below.

To finish the investigation an integral detection of the western half of the field was carried out. It was noted that the surface finds were mainly concentrated in this part. Here the squares yielded more metal finds than those adjacent to the river. It was clear that the squares were located at the sites where most metal finds are concentrated. Especially near squares ASG 003 and 008 several more fragments of iron ore and slag were excavated. A large fragment of molten bronze indicates that smithing or casting of other metal than iron took place as well. At least two fragments of cast bronze were found. The polishing on one side and a rough surface on the inside suggest that the fragments were part of statues. These were probably broken up to recuperate the metal for reuse. Apart from a few coins no identifiable objects were discovered.

The identification and condition of the metal finds

Most identifiable Roman finds are iron nails. Due to the corrosion most iron implements are not identifiable other than in general terms as hook, peg or blade. Objects of lead and bronze are scarce. One lead object may be identified as a weight of a fishing net. The rest of the lead and almost all of the bronze is scrap metal. The exception are the coins which are recognizable, but not in all cases immediately identifia-

		ASG 001 : 0-10m	ASG 001 : 10-20m	ASG 002: 0-10m	ASG 002: 10-20m	ASG 003: 0-10m	ASG 003: 10-20m	ASG 004: 0-10m	ASG 004: 10-20m	ASG 005: 0-10m	ASG 005: 10-20m	ASG 006: 0-10m	ASG 006: 10-20m	ASG 007: 0-10m	ASG 007: 10-20m	ASG 008: 0-10m	ASG 008: 10-20m	ASG 009: 0-10m	ASG 009: 10-20m	ASG 010: 0-10m	ASG 010: 10-20m	southern part field	western part field	subtotal	Total	
Iron	nail	10		9		1	2	2		2	1			9	9		14		7	9	9	1		85	253	Iron
	screw/bolt	1															2		1					4		
	wire	4				5				3		2		2	2		1		1	1	2	2		25		
	hammer																1							1		
	ring																				1			1		
	tool	6								6	1			5	1						3		1	23		
	hook			1							1						2		1	1	3			9		
	peg?										2									1				3		
	blade			1				1				2		4	1		1		1	4	3	1		19		
	disc					1																1		2		
	horse shoe																					1		1		
	tubular element																1							1		
	S-shaped element																			1				1		
	angular object													1										1		
	hexagonal element																		1					1		
	unidentified	9		31		8		3		4	1	2		5	4		3		2	4				76		
Lead	sheet																			1		1	4	6	24	Lead
	angular object											1												1		
	plumbing														1									1		
	unidentified	4		2		1					1			2	3		1						2	16		
Bronze	cow bell											1												1	4	Bronze
	cross shaped																						1	1		
	unidentified														1							1		2		
Unidentified	iron slag?	12		4				8		32	3	4		35	32		30		7	7	12		8	194	194	Iron slag?
Steel	angular object													1									1	2	11	Modern
Aluminium	unidentified																1				1		2	4		
Modern	waste					1	4																	5		
		46		48		17	6	14		47	10	12		64	54		57		21	29	34	8	19			

Table 1. Metal finds from *Ammaia*.

ble due to corrosion. There are two of which the condition is better. These are probably silver coins, but their green coloured corrosion may indicate the presence of a high copper content or even copper core. Especially the coins retrieved from the ploughed field show erosion on the edges and surface. Among the identified Roman coins we distinguish coins struck for Decius (249-251), *Divius Claudius* (post 270), Victorinus (?) (268-270), Constantinus I or II (?) (312-319), Crispus or Licinius II (321), Constans II (350), Constans II (352-361) and Magnentius (350-353) (Fig. 72). As almost all metal finds were recovered in the top of the subsoil they have been sensitive for influences of weather and agricultural or other soil disturbing activities.

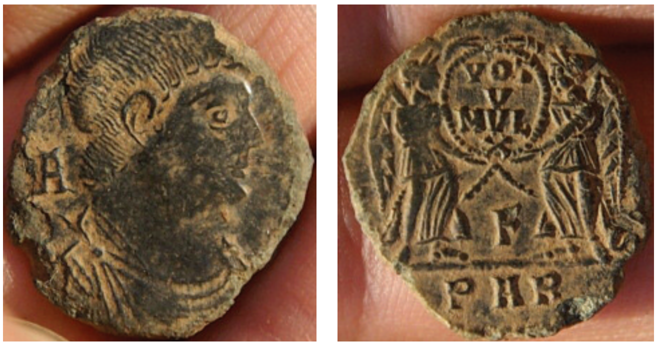

Fig. 72 Obverse and reverse of a coin of Magnentius (350-353 AD; RIC VIII Arles 171) from the western edge of the field adjacent the museum (photo A. Bosman).

Conclusion

The use of metal detectors in archaeological fieldwork has been a controversial subject in the past, but more recently, detectors are increasingly seen as tools which, when employed well, increase our understanding of the site. Most often they are used in field projects involving excavation, and often good use has been made of the instruments to study spoil heaps (e.g. Millett 2007). But the metal detector has also proven its value as a technique for survey based remote sensing and identifying activity areas within a site. It has its limitations, as under ideal circumstances it reaches only up to 12 inches below the surface; in a rocky soil this is even considerably less. Especially the test-research in two specific areas of *Ammaia* was of great use as it could be helpful to bring it in line with zones covered by other techniques. In the forum zone, the metal detecting brought additional elements for interpretations, suggested by geophysics, of the presence of water conducting systems, such as an aqueduct crossing the forum square and a basin or fountain near the temple podium. In the extra-mural zone between town and river the metal detector survey suggests interpretations of buildings found by magnetometer survey as being connected with metal works and small suburban industry, a suggestion also corroborated by the general artefact collections in this arable area.

II.5.H DIGITAL DATA MANAGEMENT AND INTEGRATION AT *AMMAIA*

E. Paliou

Introduction

In the last two decades archaeological research at *Ammaia* has offered an unusually large amount of diverse multidimensional datasets derived from excavation, geophysical survey (magnetometry, earth resistance, GPR survey: chapter II.5), topographic survey (chapter II.2), aerial photography (chapter II.3), terrestrial laser scanning, and 3D reconstruction of buried architectural remains (chapter III.3). These datasets have *per se* offered invaluable information for many different aspects of the Roman town. The collection and integration of digital data at *Ammaia* aims not only to find ways to preserve this information, but also to assemble and interrelate fragmented data into a more informative whole, so as to increase their interpretive value. For the implementation of these aims a number of digital tools are being employed. Since most of the datasets consist of spatially referenced information the use of Geographical Information Systems (GIS) has been an integral part of data management. Furthermore, as *Ammaia* has been developed into an open lab for experimentation within the framework of the Radio-Past project, a number of other digital tools for the collection and analysis of archaeological data have been tested; these are the products of collaboration among multidisciplinary research teams and are employed for more specific data processing and visualisation tasks. In this section primary emphasis is given to GIS-based applications, as these are the core of digital data management at *Ammaia*.

Objectives of spatial data management and integration at *Ammaia*

Data integration in a GIS significantly facilitates the interpretation of geospatial information, either by simply enabling the combined visualisation and interrelation of different datasets, or via the use of spatial analysis and statistics. The development of the GIS database for *Ammaia* was guided by two main objectives: firstly, to produce spatial representations that sufficiently describe the nature and complexity of the multidimensional archaeological record of the Roman site; and secondly, to permit the integration, exploration and formal analysis of the collected data in ways that enhance interpretations.

GIS provides various tools for the management, visualisation and analytical examination of archaeological datasets. Exploratory data analysis (Conolly and Lake 2006: 112-148) is frequently used for the classification of excavation data on the basis of their location and attributes, and the identification of statistically meaningful relationships in the excavation record. Furthermore, in recent years the benefits of data integration in the context of multi-method geophysical surveys have increasingly been acknowledged; the comparative evaluation of results obtained with various geophysical methods that record different physical parameters of the subsoil, such as magnetometry, earth resistance survey and Ground Penetrating Radar (GPR), can contribute to a better definition of the location, depth and geometry of archaeological bodies and help avoid misinterpretations that are easily made with one method survey (Piro, Mauriello and Cammarano 2000; Nuzzo, Leucci and Negri 2009). To date, various data fusion techniques have been proposed (Kvamme 2006b) for merging the results of different geophysical prospection methods into a single map or 3D representation (section II.5.e). The application of such techniques could enhance the interpretations of geophysical datasets, as they bring together complementary information about subsurface features and have the potential to express simultaneously robust and subtle geophysical anomalies; in this way patterns could be revealed that would not have been observed, if each dataset was examined in isolation (Neubauer and Eder-Hinterleitner 1997). Furthermore, the integration of geophysical and geoarchaeological data (e.g. coring survey results: chapter II.1), could prove particularly useful for cross-validating survey results and verifying the presence (or absence) of features that may still lay buried underground. Finally, GIS provides many tools for the additional analytical examination and interpretation of survey outcomes, while it can also incorporate the results of analyses performed with the use of external programs in the form of tabular data.

A first step for the successful implementation of the processes described above is the efficient representation of the two- and three-dimensional datasets that comprise the archaeological record. Traditionally, the integration of geospatial data in a GIS involves the overlaying of georeferenced[1] thematic maps in two dimensions. Furthermore, GIS can customarily produce seemingly 3D representations (2,5 D: Fig. 73a) by recording the third dimension (e.g. elevation) as an attribute of a set of known x and y coordinates (Wheatly and Gillings 2002: 241; Conolly and Lake 2006: 38). Nonetheless, in this case GIS data structures are not based on three independent x, y and z axes and in that sense they are not fully 3D (Harris and Lock 1996). Due to this reason conventional GIS systems have limited 3D functionality when it comes to visualising real-world objects or performing analysis in 3D space. However, the multi-dimensional datasets collected at *Ammaia* require on many occasions the representation of archaeological entities as fully 3D objects. Not only excavation data derive from a three-dimensional context, but also geophysical datasets, namely GPR data, can be better understood and interpreted in three dimensions. Furthermore, the recording of archaeological features with digital instruments (total station and terrestrial laser scanning) and the interpretation of excavated data by means of 3D reconstruction makes 3D visualisation an integral aspect of data integration at *Ammaia*.

Despite the traditional representational and analytical limitations of GIS databases, some of the latest versions of commercial GIS software offer opportunities for incorporating certain types of 3D geometry, as well as importing models created with 3D modeling packages. The implementation of the spatial database of *Ammaia* seeks to take full advantage of these possibilities for the efficient visualisation and interpretation of research results, and their communication in a comprehensible way to scholars and the public.

Choice of software

Having in mind the particular needs of archaeological research at *Ammaia*, Esri´s *ArcGIS* software was preferred from other commercial and open source GIS packages (e.g. *GRASS, gvSIG*) for a number of reasons: a) it is a popular software and industry standard that produces widely readable files; b) it provides more opportunities for the visualisation of archaeological 3D entities when compared to other GIS solutions; c) it can import 3D data created with a variety of computer programs, such as *AutoCAD* and *3ds Max*, which are employed extensively within the Radio-Past project; d) it is a widely used software for the integration of geophysical datasets via data fusion methods; e) it provides a complete set of tools and extensions for the spatial and statistical exploration of geophysical and excavation datasets (e.g. Geostatistical Analyst).

Besides *ArcGIS*, software solutions that are currently developed by multi-disciplinary research teams and aim to meet the particular needs of archaeological research, are being tested for particular data management and visualisation tasks. *Reveal Analyze*[2], a program developed by Brown University for the collection, recording, imaging, analysis, and publication of archaeological datasets, is being used for the management of excavation data together with *MS Access*. Furthermore, *Archaeofusion*, which is the product of a research project undertaken by the Centre of Advanced Spatial Technologies at the University of Arkansas, is used for the integration and fusion of geophysical datasets.

Data integration

3D visualisation of excavation and survey data

As mentioned above, the efficient representation of archaeological entities in 3D is an important requirement for the successful implementation of various data integration tasks at *Ammaia*. On many occasions, visual interpretations are based on draping excavation and geophysical datasets upon isometric topographic models; such visualisations can help the interpretation of prospection results as differences in the intensity of measured physical parameters of the subsoil can be due to variations in topography (Gaffney and Gater 2003: 112). In addition, topography could have affected the planning of the Roman town, and more specifically the orientation of the urban grid and buildings (see chapter II.2). The production of an extended isometric topographical model for *Ammaia* that incorporates all available spot height measurements was underlain by the same considerations discussed in chapter II.2 regarding quality, accuracy as well as suitability for particular visualisation tasks. The aim was to produce a model that well represents in 3D the altering relief of the terraced part of the intra-mural area, as in that case the changes in topography determined the survey limits and potentially affected the responses recorded by geophysical instruments. In addition, efforts were made to produce a more realistic representation of the terrain that included the modern roads as breaklines (see chapter II.2), but lacked pronounced interpolation artifacts that affect visual quality, such as “bull eyes” and linear anomalies. A model that has the above characteristics (Fig. 73a) was achieved using both Inverse Distance Weighted (IDW) and

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[1] Meaning that their exact positions in space are defined according to a specified geographic coordinate system.

[2] REVEAL (**R**econstruction and **E**xploratory **V**isualization: **E**ngineering meets **A**rchaeo**L**ogy: http://vision.lems.brown.edu/project_desc/Reveal) is a package, cooperatively developed by Brown University (School of Engineering, Laboratory for Man/Machine Systems), the University of North Carolina (Department of Electrical and Computer Engineering) and the Institute for the Visualization of History (USA).

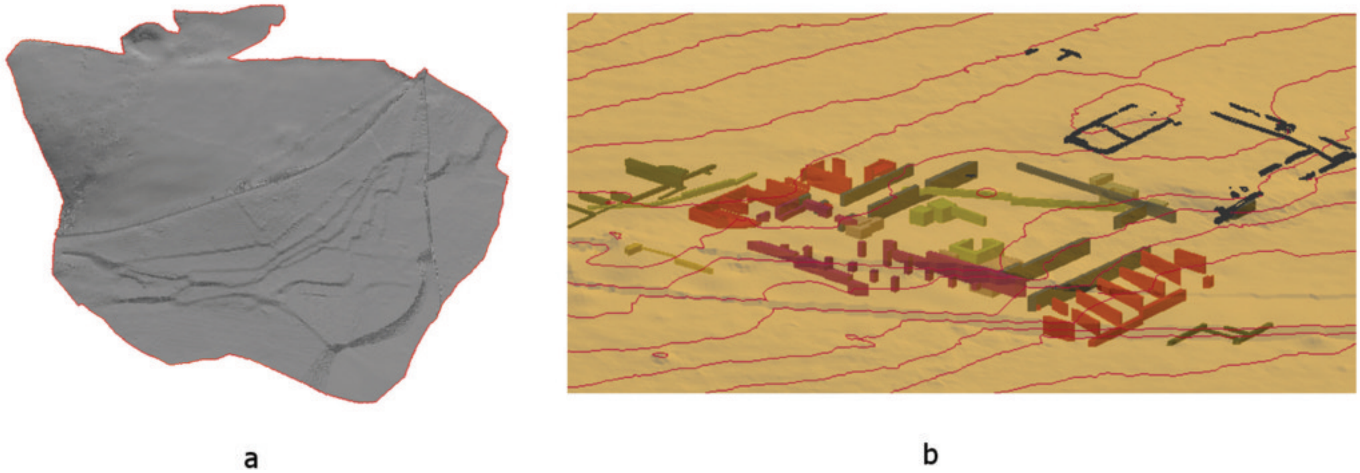

Fig. 73 The isometric terrain model of *Ammaia*, b. 3D GPR interpretation and 2D excavation data from the forum area integrated with the isometric terrain model and contour data.

Kriging interpolation methods: the part of the model east of the modern road that traverses the settlement was created with IDW interpolation (12 neighbours), which permits the inclusion of breaklines and produces a digital terrain model (DTM) in which the terraces are strongly indicated. The DTM for the area west of the modern road was produced with the application of Kriging algorithms, so as to avoid the accentuated bull-eye effects that were particularly apparent at the south-west, when using IDW interpolation. The two models were merged into a single raster that was subsequently converted to a 2,5D terrain model (TIN)[3].

DTM of excavated areas were also used to give a 3D impression of two-dimensional CAD drawings. In that case the digital drawings simply adopted the corresponding base heights (Z value) of the DTM. Other types of excavated data such as finds and sample locations recorded with a total station were included in isometric drawings as 3D plots. Finally, complex 3D entities, such as GPR interpretations (Fig. 73b) and building reconstructions, were imported as AutoCAD three-dimensional geometry (3D faces) and were converted to ArcGIS multipatch objects. The inclusion of reconstructed buildings in the GIS database permits their direct association with the excavation and geophysical survey data that form the evidence for their reconstruction. Furthermore, useful information on these models (e.g. levels of confidence for the reconstruction or suggested uses of space) can be included as tabular data and used in queries for the selection and classification of individual features.

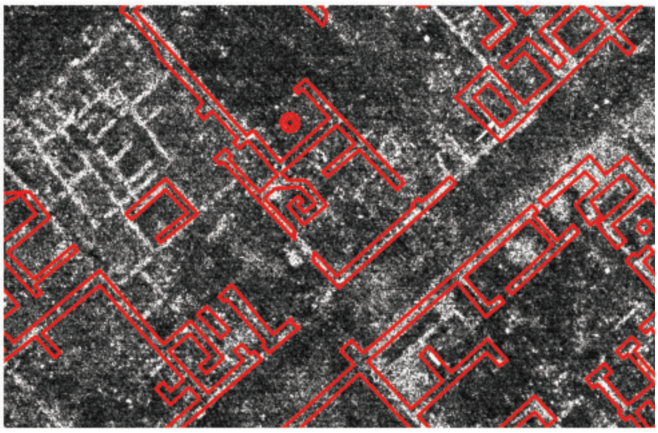

Fig. 74 A two-dimensional overlay of the vector interpretation of magnetometry survey with high resolution GPR data.

Integration and analysis of excavation and survey data

Integration and data fusion of geophysical datasets

A principal aim of the archaeological research at *Ammaia* within the wider framework of the Radio-Past project is the valorization of the Roman town using multiple geophysical methods which can offer complementary information about buried archaeological features. The inter-relation and cross-validation of digital datasets produced by these surveys is far more effective when results are examined together in their common spatial context rather than being inspected as distinct mappings. Various data integration and fusion techniques for the interpretation of geophysical datasets were adopted at *Ammaia*. These could be classified into graphical, discrete and continuous approaches (Kvamme 2006b) and are explained in detail in section II.5.e. The above techniques have been implemented using *ArcGIS* and *Archaeofusion* software with various levels of success depending on the nature of collected data, the number of

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[3] The Root Mean Square error is around 0,174056 for the east part of the model and 0,14678 for the west. The estimation of error for the eastern part of the DTM was made using an IDW model (10 to 15 neighbours) implemented with Geostatistical Analyst. However, the final terrain model of the terraced areas was created with Spatial Analyst, as Geostatistical Analyst does not allow the use of breaklines when implementing IDW algorithms.

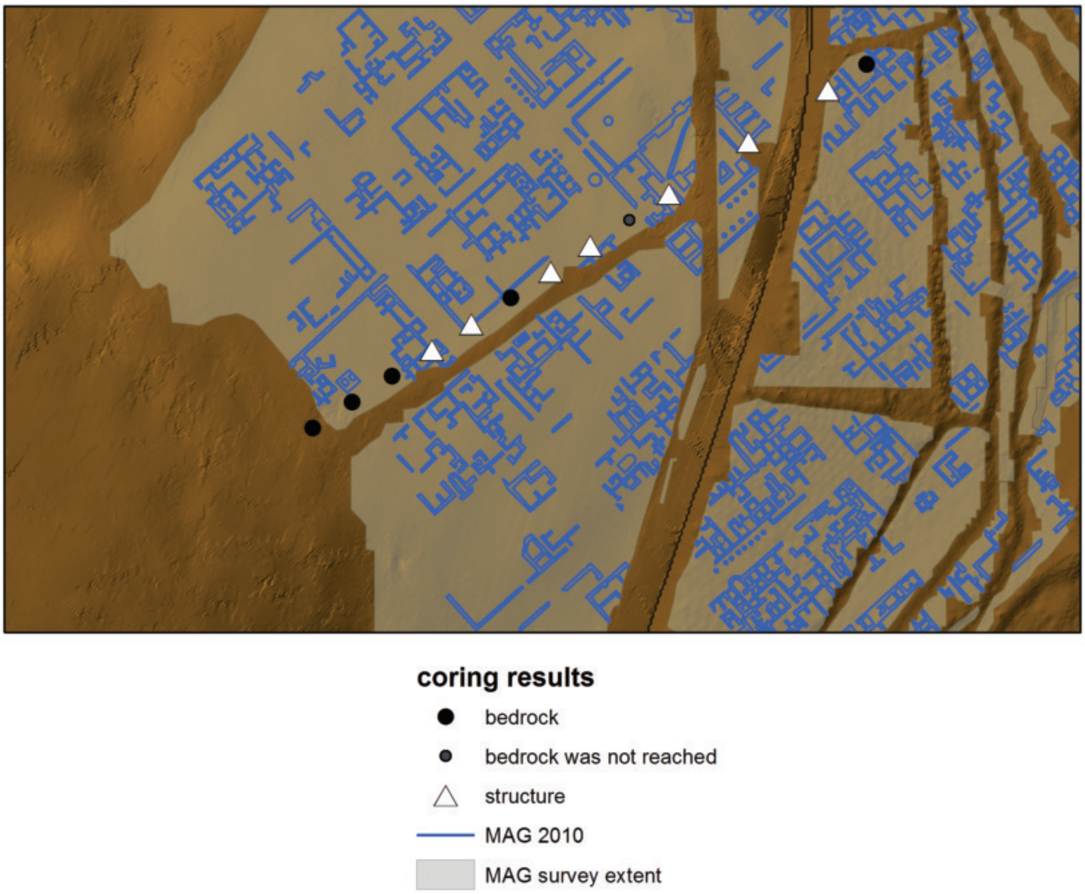

Fig. 75 Coring samples indicating buildings (white triangle) and bedrock or spoliated street locations (black dot) against the results of magnetometry survey.

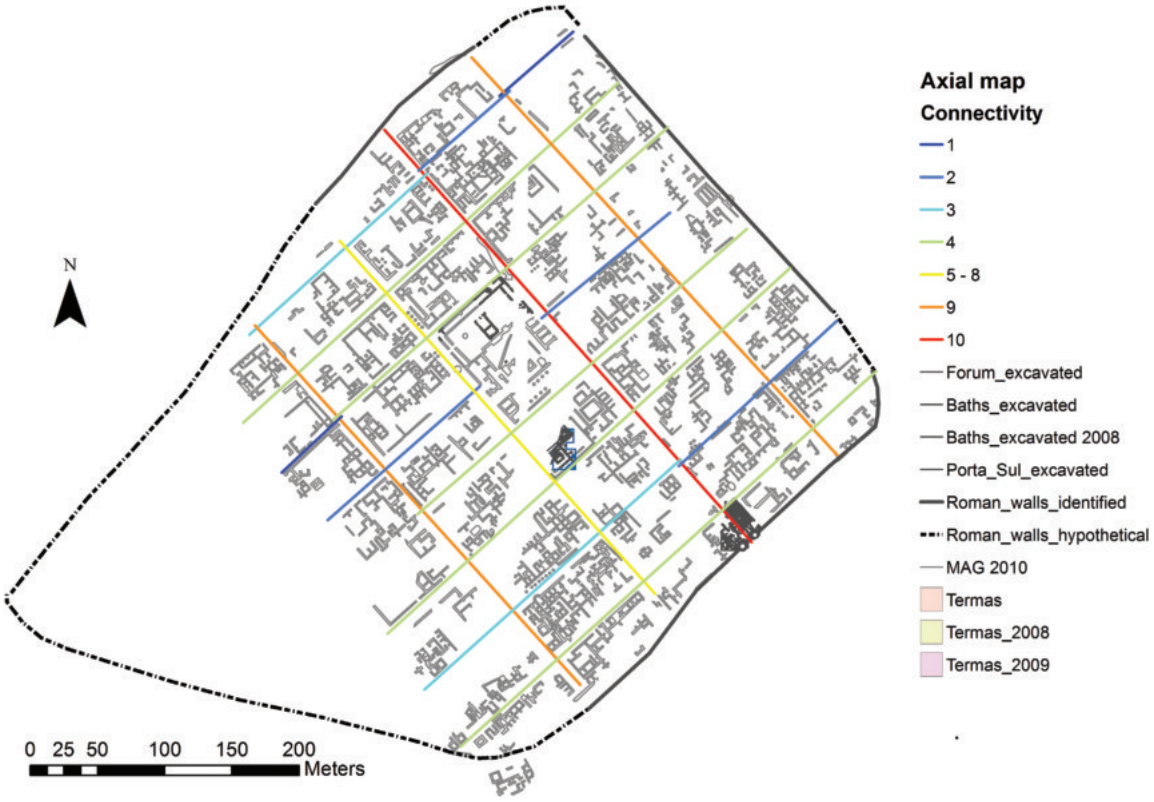

Fig. 76 The Space Syntax measure of “Connectivity” indicating the number of intersections for each street segment.

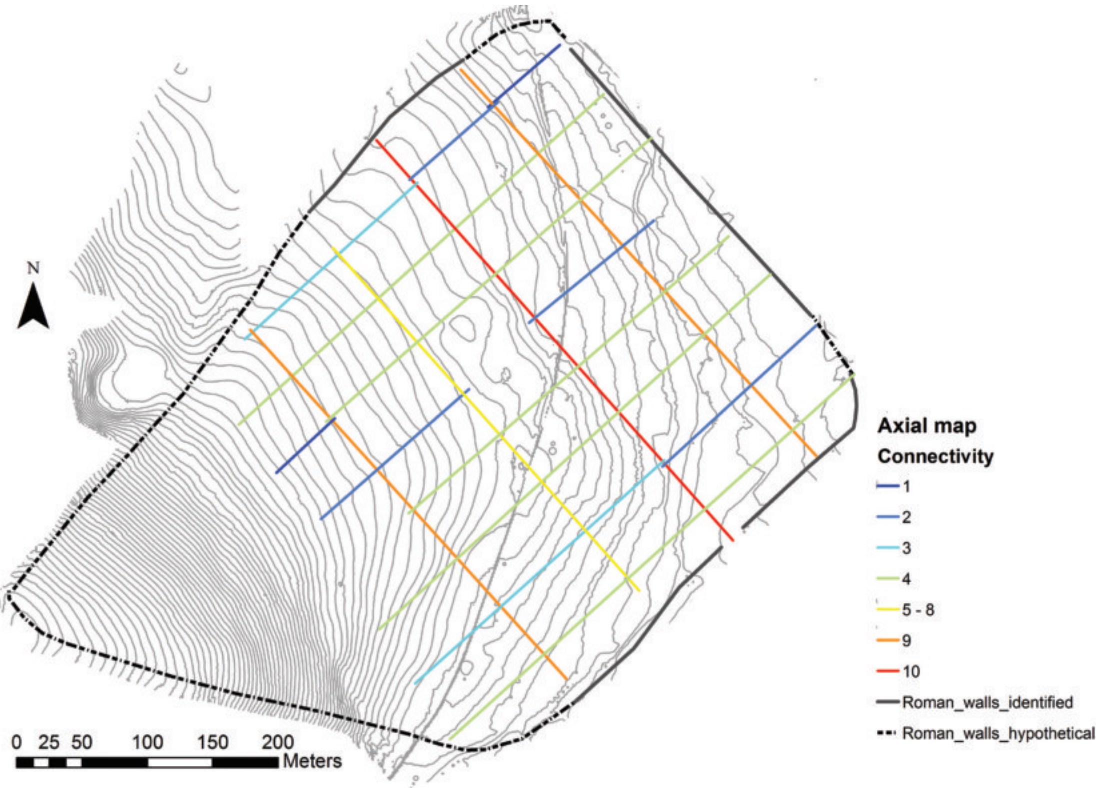

Fig. 77 The "Connectivity" measures of the street network of *Ammaia* examined together with topographic contour data.

combined datasets and data quality issues. Most times simple graphical two-dimensional overlays of vector data upon raster images provide important complementary information (Fig. 74) or highlight inconsistencies in the datasets that help avoid misinterpretations. Continuous integration methods have proven more useful where there are good quality high resolution datasets from three different surveys, such as those collected at the area of the forum (section II.5.e).

Integrating geophysical, topographical, and geoarchaeological data

The integration of geophysical surveys with topographical and geo-archaeological data contributes further to the interpretation and cross-validation of datasets. For example a simple overlay of geophysical and coring survey results can give further evidence on the presence or absence of walls and suggests inconsistencies in interpretations. In the case of *Ammaia* the results of coring survey (see chapter II.1) indicating the presence of buildings correspond on most occasions to the results of magnetometry survey (see section II.5.b) and confirm the suggested interpretation of geophysical anomalies (Fig. 75). Furthermore, the overlay of geophysical datasets such as resistivity on the DTM of the site has been used to explain differences in the magnitude of responses, especially in the area of the forum (Verhegge 2010: 113). Finally, the visualisation of 3D GPR vector data (section II.5.c) together with the isometric terrain model and digital drawings of excavated remains gives a very informative picture on the nature, form and position of preserved architectural features that would not have been possible with two-dimensional overlays (Fig. 73b).

Computational analysis of survey results

The integration of results of computational analyses produced with external programs into a GIS environment offers even more possibilities for analysis and interpretation. The street network of the Roman town, as revealed through the interpretation of magnetometry data (see II.5.b), can be analyzed with urban network analysis methods, such as those that are under the umbrella of Space Syntax (Hillier and Hanson 1984). This approach can give insights into aspects of movement, social activity and urban organization in Roman towns (Kaiser 2011), especially if the estimated graph measures are examined together with topographic data and geophysical survey interpretations suggesting the function of buildings. For example, the results of network analysis performed with *Depthmap*, a software developed at University College London, shows that the NW-SE streets have high measures of "Connectivity" and "Control" when compared to the SW-NE streets (Fig. 76). This would suggest that NW-SE streets were important for channeling movement through the Roman town (see Kaiser 2011: 55-56). The integration of the results of network analysis with contour data offers a plausible explanation of why this pattern has emerged (Fig. 77): it appears that the city grid was laid in such a way so that the NW-SE streets are parallel to the topographic contours[4]; such arrangement would have greatly facilitated pedestrian and vehicle movement towards NW-SE direction. On the other hand, movement along SW-NE streets that are laid perpendicularly to the contours would have been less easy due to more abrupt changes in slope. More insights into the social life and urban organization of the Roman town will be precipitated, if graph measures are associated with the presence of public and private buildings identified in geophysical maps. Although the spatial network analysis of the open public spaces of *Ammaia* is still work in progress, the preliminary results suggest that integrated non-destructive methods show great potential for enriching our knowledge on ancient street networks through an analytic examination of the data by means of spatial analysis.

Conclusions

The integration of geospatial datasets collected at *Ammaia* piece together a picture of the Roman town that would not have been possible in the past without excavation. Above only some examples of the many ways in which archaeological interpretations have benefited from the combined examination and analysis of archaeological datasets were presented. The use of computational tools and methodologies at *Ammaia* has been essential for the interpretive process and the communication of scientific results to scholars and the public. The creation of the spatial database of *Ammaia* and the employment of computational techniques [the employment of computational techniques] for data analysis is an ongoing work that promises to offer even more opportunities for archaeological interpretation in the future.

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[4] This is more apparent at the NW where there is less evidence for human intervention in the landscape after the Roman era.

II.6 ARTIFACT SURVEY

D. Mlekuž, D. Taelman

Introduction

This chapter presents the results of a series of experimental artefact surveys performed on the area the of the Roman town of *Ammaia* and discusses the relation of the survey results to the results of remote sensing techniques, primarily geophysics.

On complex sites such as *Ammaia*, that were settled and used for centuries, we cannot assume any direct relation between structural remains, visible traces using remote sensing technologies and the surface record of artefact distribution. This is because the formation of the surface record on complex sites is an intricate palimpsest of processes. It is, therefore, naive to expect that artefact survey reveals a functional division of the structures detected using remote sensing techniques. Instead, the surface record should be seen as a material residue of long term mundane practices, such as cleaning, dumping and abandonment.

Due to the large quantities of surface material, the traditional way of Mediterranean field survey on complex sites is to limit the collection to the diagnostic sherds only and count sherds and building material within the regular grid (Bintliff and Snodgrass 1988). However, there are many drawbacks to this approach. First, it is extremely difficult to recognise diagnostic sherds on the field, especially for the inexperienced students who are the usual workforce. A more important issue are, however, the extremely complex processes behind the formation of the surface record. Complex sites are marked by a long history of occupation, a series of re-buildings, changes of function and processes of abandonment and post-depositional disturbance. Thus, for complex sites, simple counts do not give enough information about the processes that formed the distribution.

Instead of counts or quantities, we decided to study the composition of the surface record. In this perspective, the relative frequencies of material categories and patterns of their absence and presence within the samples are more indicative than raw counts. Moreover, sheer number of material and many different categories of collected material necessitate the use of a multivariate approach. Thus, instead of observing counts of different material categories, the samples are compared between themselves using multivariate statistical methods, such as clustering and factorial analysis.

Artefact survey is, therefore, not about raw counts of material, it is about detecting complex patterns in the surface distribution.

Collection

In the summer 2010, an area of around 0.8 hectars was surveyed, under the supervision of Dimitrij Mlekuž, on the recently ploughed field opposite the museum. The area lies outside the eastern city gate of *Ammaia* on a low terrace above the River Sever. The field was divided into 10 x 10m grids, oriented according to the *Ammaia* survey grid, thus using the same grid as geophysical prospections. A first test survey (S1) was performed on an unploughed field, where only 10 grid squares were surveyed; a second, larger survey (S2) was performed just after the field was ploughed. The second survey was achieved with the help of students from the Universities of Cassino and Ghent. In total 80 grid squares were surveyed. Collection time was limited to 10 minutes, collectors were instructed to collect fragments of all material larger than 1cm. As ploughing was shallow (max. 20cm deep), artefact visibility was generally good and uniform over the surveyed area.

In the same season, a preliminary shovel pitting survey (SP) was performed on the northern part of *Ammaia*. The goal was to estimate the quantity and composition of topsoil material within the limits of *Ammaia*, on the areas that are closed to surface survey. Only 12 shovel pits in a 50 x 50m grid were excavated in addition to two shovel pits excavated on the forum area. The shovel pits have standard dimensions of 50 x 50cm and were excavated to the depth of the topsoil (generally around 20cm). In this way, they sample the topsoil material only and do not disturb the underlying archaeological deposits (Fig. 78).

The geophysics survey on the field opposite the museum, performed by Eastern Atlas in the Spring of 2011 (see section II.5.f) demonstrated the presence of a road leading from the River Sever to the eastern towngate and of a series of walls, dividing the extramural space into several large compartments. Compartments located next to the road are partially built over, as clear traces of buildings with internal divisions can be observed.

In summer 2011 a "targeted" (TS), unsystematic survey was performed, supervised by Devi Taelman. Through the study of the distribution of the artefact surface record, this targeted survey aimed to obtain more information on possible functions of the geophysically identified features. For this, 10 sampling units were set out with a location based on the magnetometry data. Areas where subsurface structures were identified, as well as areas without structures were

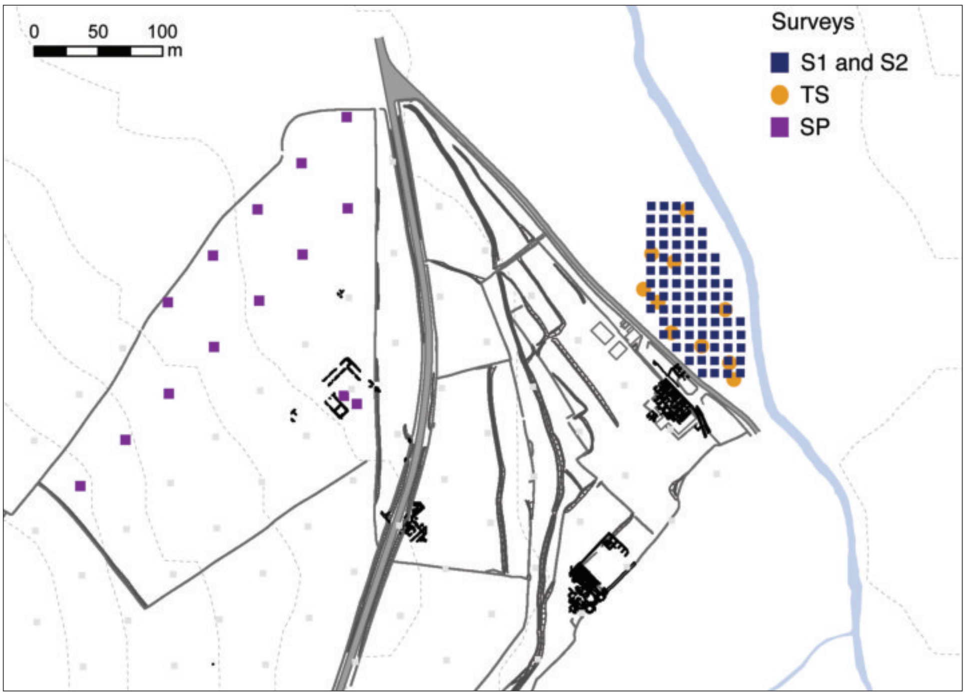

Fig. 78 Surveyed areas.

selected for the artefact survey. The total surveyed area measured 785.40m^2 (Figure 78). All cultural material larger than 1cm was collected, without a limit on the collection time. Ploughing was shallow (max. 20cm deep) and artefact visibility was generally good and uniform over the surveyed area.

All collected material was washed, classified and quantified under the supervision of pottery specialist José Carlos Quaresma.

Results

Material

In total, 4111 pieces of material were collected. More than 93% of the collected fragments can be classified as building material, including tiles, brick, fragments of worked stone and various small fragments. Among the remaining 7%, or 286 fragments, some 80% represents mainly Roman coarse ware pottery and some 20% includes Roman fine ware (mainly different types of *terra sigillata*), containers (*amphorae*), lamps and loom weights. One piece of prehistoric (probably Bronze Age) pottery was found.

Assemblages and distributions

First, assemblages can be compared on the basis of a few simple measures. The simplest is size or quantity, i.e. the number of all collected material within the collection unit. Size alone is not very informative, as it can reflect the size of subsurface assemblages or just post-depositional effects such as depth of plowing, level of destruction of subsurface deposits or other post-depositional and attritional transformations such as displacement and accumulation in depositional basins. When observing spatial distribution of sample size, three discrete zones of larger samples can be distinguished. One lies near the *Ammaia* town wall, a second large zone lies between the subsurface structures and the river and a third area extends north of the Roman road detected on magnetometer survey. This pattern could be the result of a complex interplay of many different factors, beyond our control. The only variable we can observe is the thickness of the layer with cultural material, measured during the coring survey (see chapter II.1). A coring transect over the artifact survey area shows rapid decrease of thickness of layers with cultural material, while the depth of topsoil remains constant. If the depth of the layer with cultural material correlates with the intensity and length of deposition, then the size of surface assemblage can directly reflect the thickness of the cultural layer. The large carpet of larger samples between the subsurface structures and the river could be result of this process. The wide quantity of material near the *Ammaia* wall could be explained by the thickness of the cultural layer (Fig. 79).

Second, we can compare samples based on their diversity. Diversity, as used here, is a measure of variability in the composition of an assemblage. It is composed of two components: richness and evenness. Richness refers to the number of categories of material within the assemblage; evenness describes the relative proportion of each material category in an assemblage (Grayson 1984; Kintigh 1989;

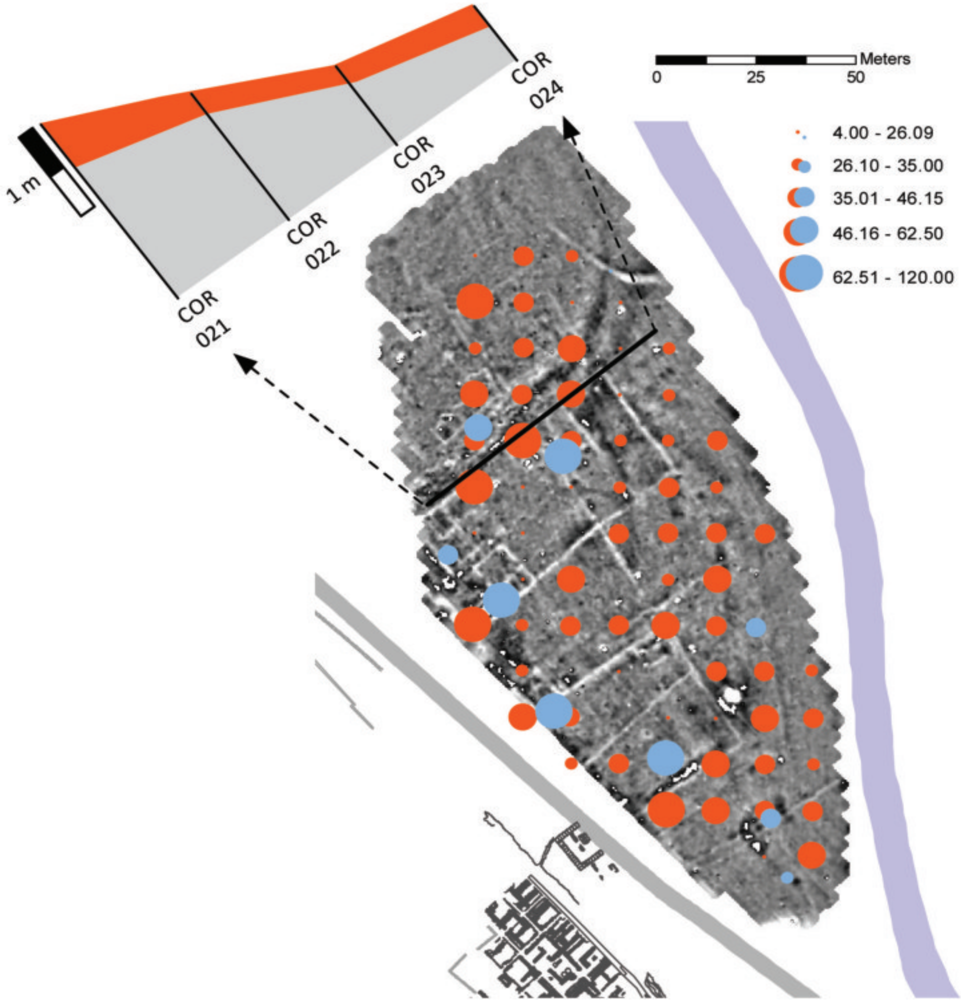

Fig. 79 The assemblage size (S2 and TS) with the depth of the layer with cultural material, derived from the coring survey.

McCartney and Glass 1990). Evenness is measured with Shannon-Wiener information statistics (H) divided by the maximum value for observed richness (Hmax). Division by Hmax removes the effect of richness and normalises evenness into the 0-1 interval. Thus the value of 1 corresponds to completely even assemblages, composed of equally distributed categories. While values close to 0 indicate very uneven assemblages, where one category dominates. Both richness and evenness are commonly used in landscape ecology and archaeozoology, and are related to information content or entropy of the sample. Thus very even samples may indicate high entropy, smoothed assemblages, heavily transformed by post-depositional processes.

We assume that samples with high information content (low evenness, high richness) are formed in areas where material comes to surface during several episodes of deep plowing and is consequently moved around by plowing and erosion. Thus, rich and uneven assemblages may indicate the sources of material, whereas less rich and even assemblages result from heavy post-depositional modification and movement of material.

For the *Ammaia* survey, spatial distribution of diversity measures indicate that richness and assemblage size generally correlate; a large assemblage means that there is a larger probability that more different categories are represented in the pattern. However there are some deviations from this pattern especially in the central area of the survey. Spatial distribution shows that evenness is inversely correlated to sample size, which further supports the hypothesis that low richness and highly even samples result from attrition of source assemblages (Fig. 80).

If we acknowledge that we are studying complex assemblages, that result from a series of complex processes and transformations, we can cope with this complexity using a multivariate statistical approach. In this way, we observe and analyse more than one variable at a time, compare

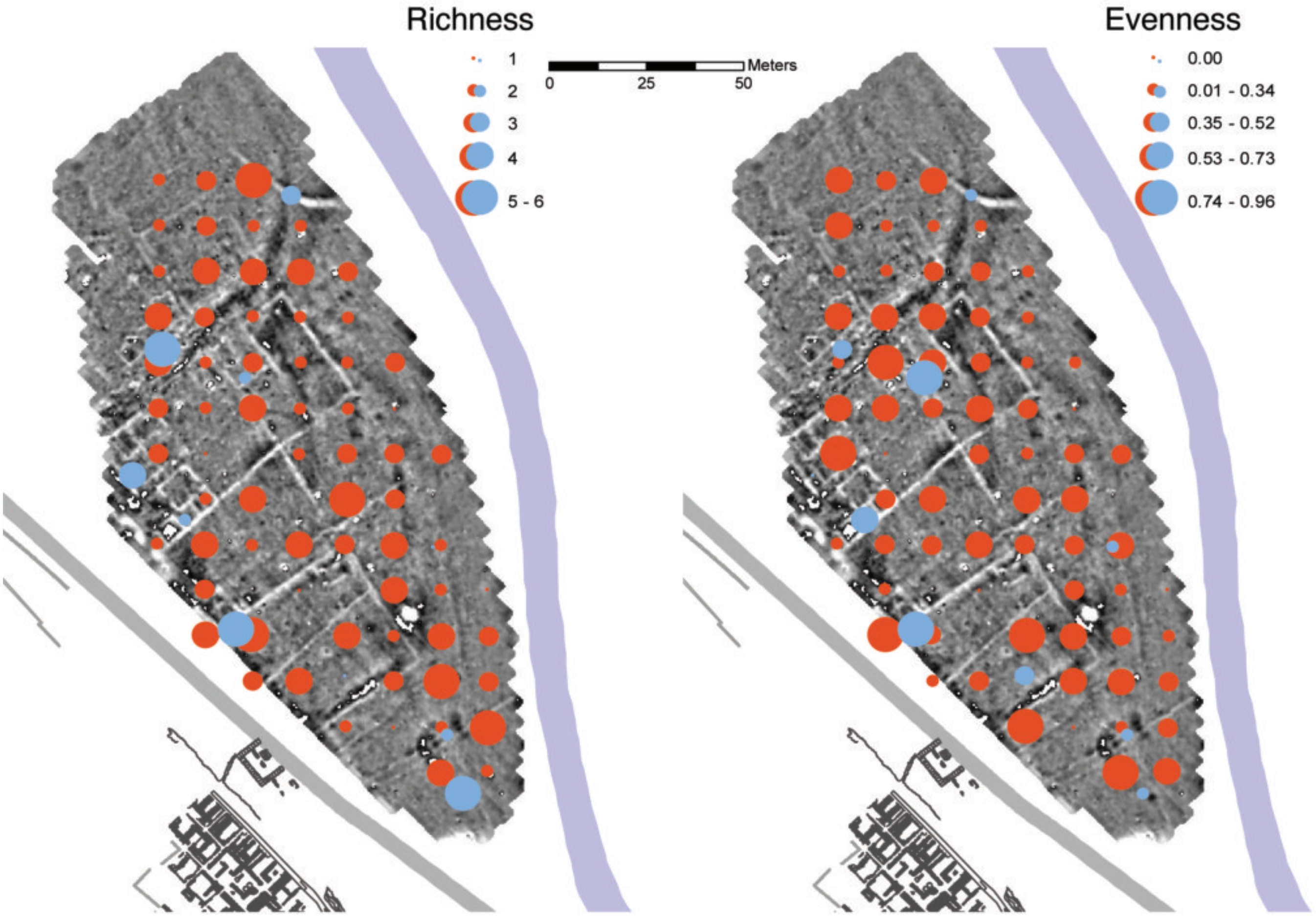

Fig. 80 Richness and evenness of collected assemblages (S2 and TS).

assemblage compositions and identify patterns behind their make-up.

This assumes that assemblages with similar composition are the result of similar processes and transformation. However, one can never dismiss the equifinality.

For the purpose of multivariate analysis, samples were transformed into n-dimensional tuples, where each dimension represents one material category. Since many categories are represented by few pieces only, categories were grouped into generalised categories of material. We described each assemblage in terms of the presence of coarse ware (mainly cooking ware), containers (predominantly *amphorae*), fine ware (with different kinds of *terra sigillata* and table ware), tiles, building material (worked stone, mortar, plaster) and fragments of building material too small to identify. The tuples were normalised, their standard score was calculated by subtracting the population mean from an individual raw score and then dividing the difference by the population standard deviation.

First, assemblages were grouped using the hierarchical clustering method. The idea of hierarchical clustering is to build a binary tree of the data that successively merges similar groups of points. Visualising this tree (dendrogram) provides a useful summary of the data. Groups that merge at high values relative to the merger values of their subgroups are candidates for natural clusters. However, hierarchical clustering should be treated with caution. Different decisions about group similarities can lead to vastly different dendrograms as the algorithm imposes a hierarchical structure on the data, even data for which such structure is not appropriate (Shennan 1988: 241-244; Baxter 1994: 140-152; Izenman 2008: 412).

The *Ammaia* dendrogram shows that samples cluster into two large natural clusters, while the second cluster can be further subdivided into three more or less natural subclusters (Fig. 81).

If we observe the grouping of variables, we can see that they form two large groups. The first cluster includes building material, where tiles, ceramic building material, and other building material behave in a similar way; the second cluster with pottery includes containers, and coarse ware and fine ware which form their own subcluster (Fig. 82).

Using k-means clustering, we identified four main groups. K-means (Izenmann 2008: 423) is one of the simplest unsupervised learning algorithms that solve the well-known clustering problem. The procedure follows a simple and easy way to classify a given dataset through a certain number of clusters fixed *a priori*.

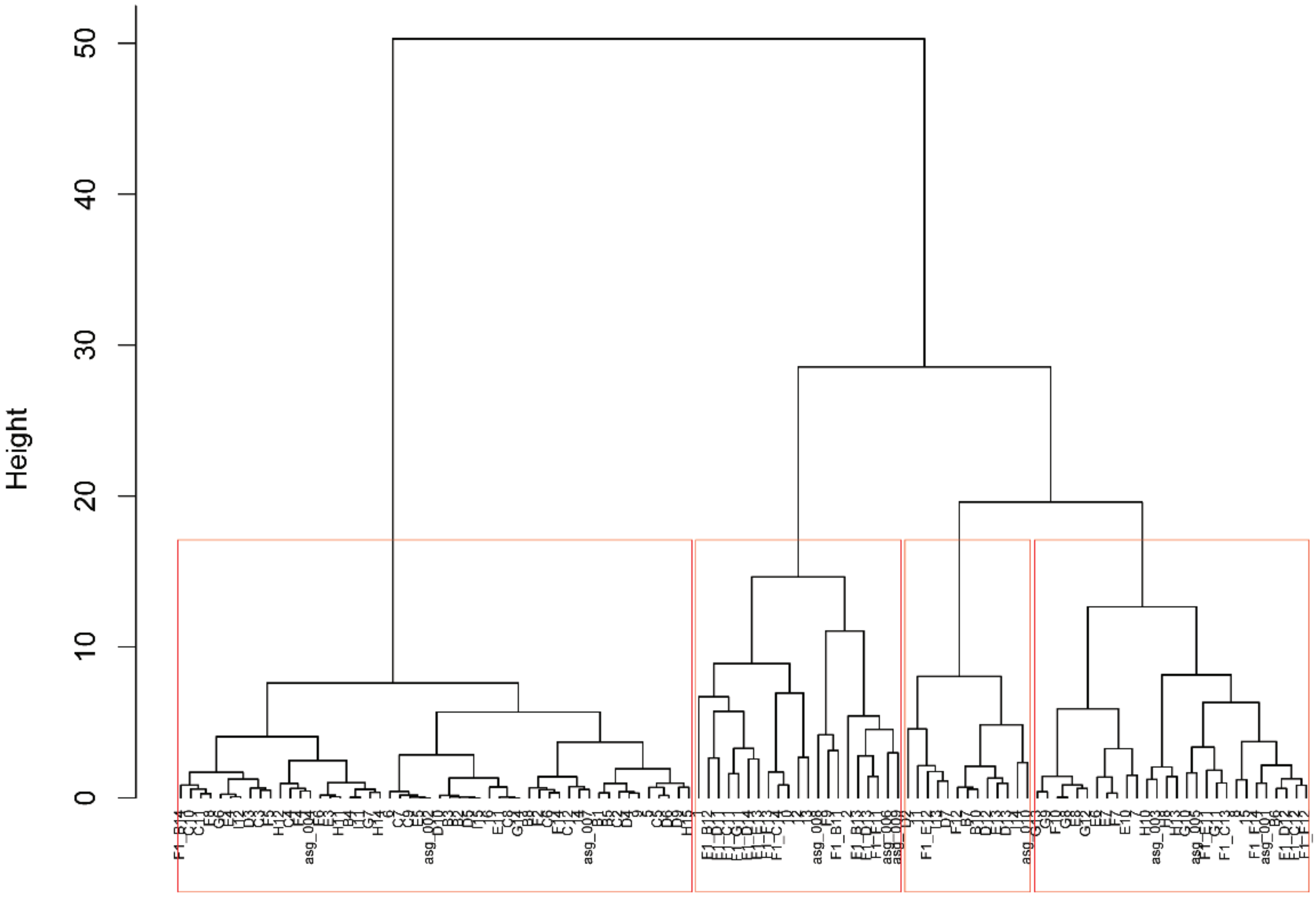

Fig. 81 Dendrogram of assemblages (S1, S2, SP and TS).

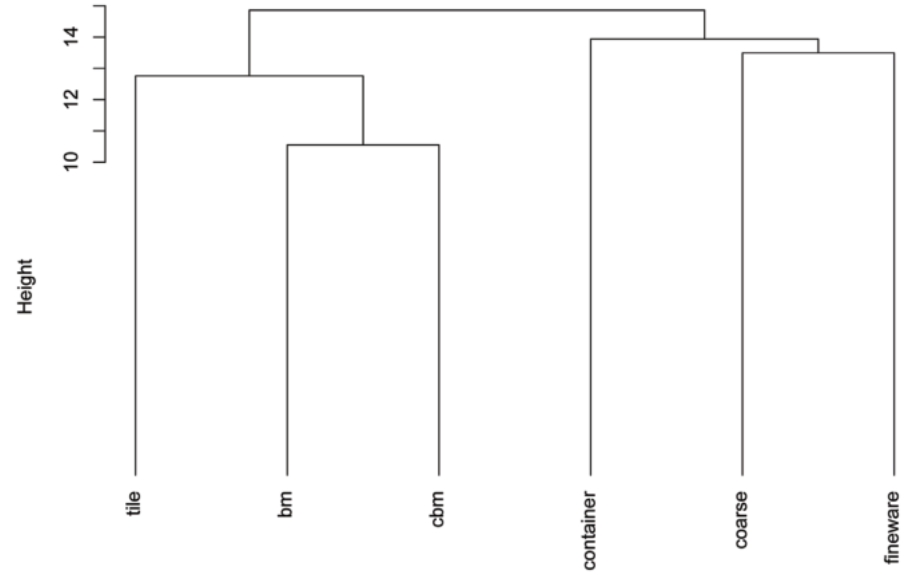

Fig. 82 Dendrogram of categories (S1, S2, SP and TS).

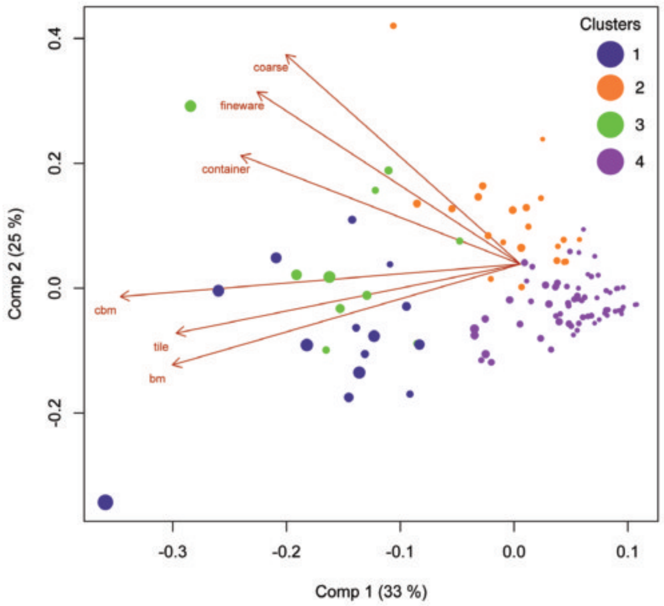

Fig. 83 Plot of k-means groups agains principal components (S1, S2, SP and TS). Size of points indicate relative sample size.

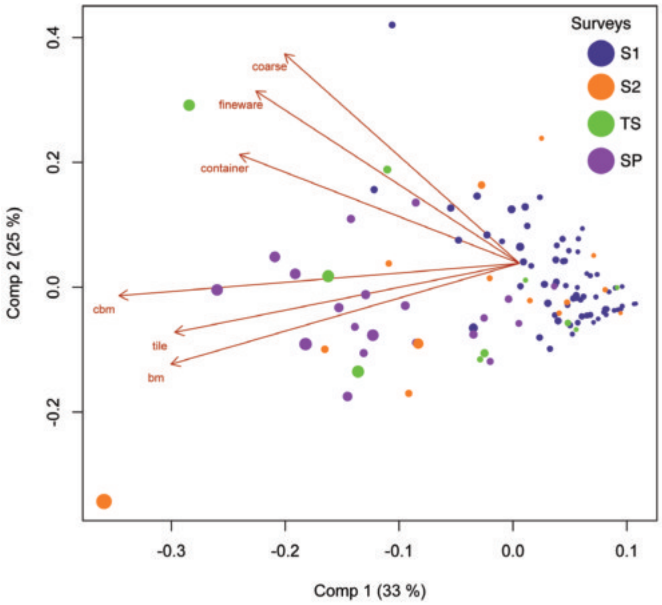

Fig. 84 Plot of assemblages from different surveys (S1, S2, SP and TS) against principal components.

Composition of clusters can be approached using principal component analysis. Principal component analysis (PCA) is a mathematical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components. The number of principal components is less than or equal to the number of original variables. This transformation is defined in such a way that the first principal component has the largest possible variance (that is, accounts for as much of the variability in the data as possible), and each succeeding component in turn has the highest variance possible under the constraint that it be orthogonal to (i.e., uncorrelated with) the preceding components (Shennan 1988: 241-270; Baxter 1994: 48-94; Izenmann 2008: 195-215) (Fig. 83).

The first principal component (x axis, Comp 1) comprises around 33 % of all variance and can be interpreted as the proportion of the building material within the assemblage. The second principal component (y axis, Comp 2) make up 25 % of variability and can be interpreted roughly as the proportion of the pottery (fine ware, coarse ware and containers) within the assemblage.

Plotting the k-means clusters against the first two principal components shows that there are no clear-cut clusters, but we can discern the undifferentiated assemblages grouped on the right which tend to diversify in two directions, towards assemblages with a more dominant pottery component on upper left corner of the graph, and others with more pronounced building material component on the lower left corner (Fig. 83).

A first group is characterised by a large proportion of (ceramic) building material and little or no pottery. A second group is defined by again a large quantity of building material but also a relative large proportion of pottery in comparison with the group 1. A third group is similar to the second, with a relative large proportion of pottery, especially fine ware in relation to the building material. A fourth group consists of generally small, undifferentiated assemblages.

If we plot the relation of assemblages from the different surveys we can see that different collecting methodologies do not have a strong influence on the composition of samples. In this way, we are able to compare the composition of the different surveys, although they were collected in a heterogeneous ways (systematic survey in a grid, test pits and “targeted” survey (Fig. 84).

Spatial distribution of the clusters shows that most of the surveyed area next to the river is covered by small undifferentiated samples (group 4), while groups 2 and 3 (assemblages with relatively high pottery contents) occur within the buildings, mainly around the walls, and on the open area between the building and the river. Cluster 1, defined by an almost exclusive dominance of building material occurs only sporadically.

The spatial correlation between samples acquired through targeted survey and systematically collected samples suggests again that the collection method has no (major) impact on the composition of assemblages (Fig. 85).

The number of excavated shovel pits is too low for any relevant conclusion; however, spatial distribution of assemblages acquired by the shovel pitting survey renders a different picture. There is a larger percentage of high information content assemblages (clusters 1-3), and much larger percentage of cluster 1 assemblages. Especially interesting is that both assemblages excavated on the forum area are classified as cluster 1, which supports the evidence from the forum excavation, where thick layers with building material

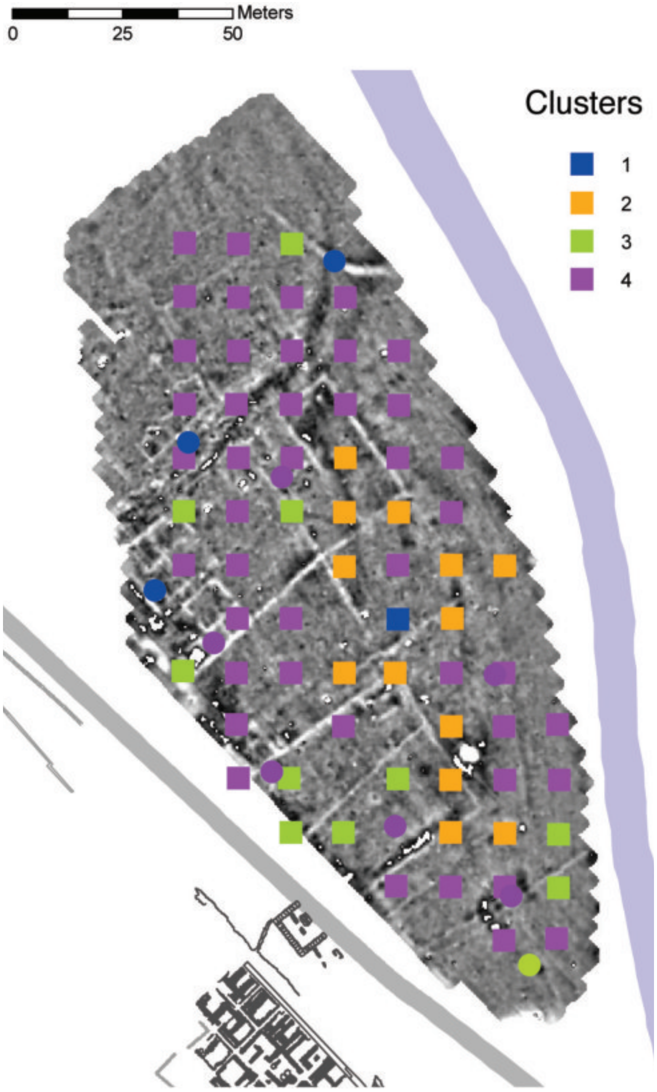

Fig. 85 Spatial distribution of k-means cluster (S2 and TS).

(mainly tiles) were recovered under the topsoil. Whether these differences result from different collection strategies or show an underlying pattern (*intra* versus *extra muros* areas) is inconclusive (Fig. 86).

Dating

Fifteen pieces of pottery were recognised as more diagnostic and well dated. A plot of date distribution shows a bimodal distribution with 10 fragments dated to the first two centuries AD, and five fragments dated to the third, fourth and fifth century AD. The presence of a relatively large number of fragments dated to the first two centuries AD indicate that the area was not cleaned and served as a depositional basin. Later dates can be interpreted as continuation of this practice or as a result of abandonment processes. Spatial distribution of the diagnostic sherds does not suggest any temporal patterning of the surface record (Fig. 87).

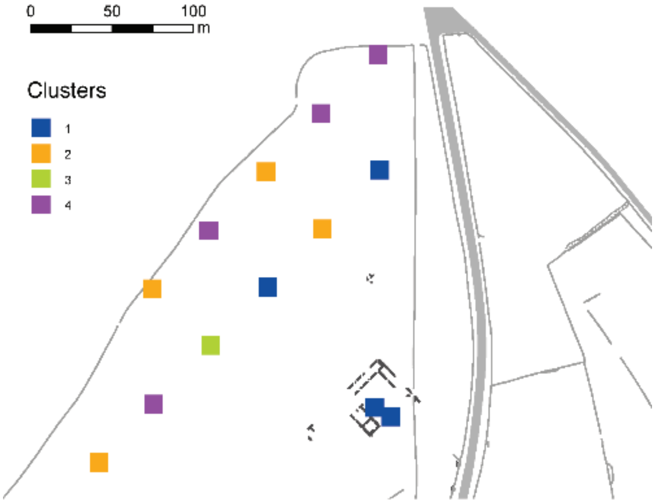

Fig. 9 Spatial distribution of k-means cluster (SP).

Discussion

Formation processes

Michael Schiffer's (1987; La Motta and Schiffer 1997) work on formation processes of the archaeological record demonstrated that what we see results from a series of processes of building, use, abandonment, and post-abandonment transformations often operating side by side and making the surface population a complex palimpsest of different formation processes.

Most of the pottery enters the archaeological record through depositional practices that have a clear spatial dimension. Artefacts discarded at their locations of use are termed *primary refuse*; those discarded elsewhere are known as *secondary refuse*. The primary refuse is rare; people tend to clean our living and working areas. An unmistakable characteristic of secondary refuse distributions in most settlements is clustering. People tend to dump trash away from the place it was produced where others have previously dumped trash, as a result, concentrations arise. This, of course, means that surface sample does not reflect a frozen snapshot of social organisation, and that survey will not necessarily reveal the functional variation within a town.

Life in a Roman town produced huge quantities of waste, not only organic but also pottery. An estimate based on Peña's (2007) work on lifecycles of Roman pottery shows that enormous quantities of material were discarded and disposed of somewhere. In addition, there is also a complex dynamics of abandonment. The abandonment of places sets in motion another set of processes that deposits artefacts; the most important of these is the *de facto* refuse deposition. *De facto refuse* consists of the tools, facilities, structures, and other cultural material that, although still usable (or reusable), are left behind when an activity area is abandoned. Thus, within a single site, one may find considerable variability in refuse production during the abandonment.

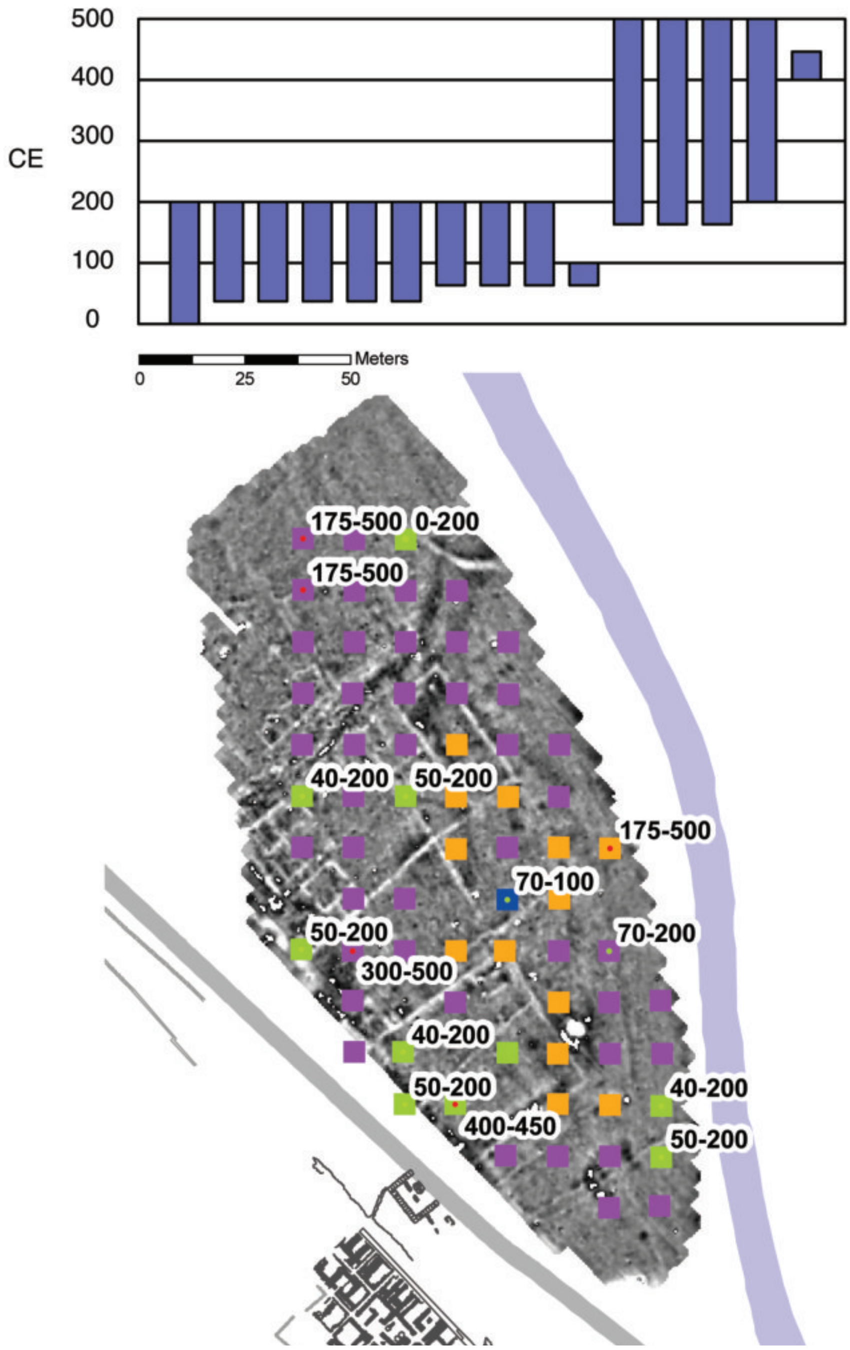

Fig. 87 Dates of diagnostic finds and their spatial distribution (S2 and TS).

The earliest-abandoned buildings contain scarcely any *de facto* refuse and were often reused as dumps. In contrast, late-abandoned houses contain many restorable pots, and other usable artefacts – *de facto refuse* – and were not reused as secondary refuse dumps.

The dominant component of *Ammaia* survey assemblages is building material, suggesting that abandonment processes and structural collapse are the main cause of variability in the surface record.

The pottery component in the assemblage can be interpreted as a result of dumping. Ethnoarchaeological evidence suggests that some domestic refuse can be disposed of in out-of-the-way places around the residential compounds, within features that constitute an enclosed depositional basins, such as abandoned rooms, buildings and pits, particularly favoured for this purpose. A substantial portion of domestic refuse is disposed of outside, but within a short distance of the residential compound (Schiffer 1987).

This pattern can be observed in the area surveyed near the river. Most of the pottery rich assemblages (clusters 2 and 3) can be found behind the walls of the compounds, suggesting that the area between the compounds and the river was used as a secondary refuse area. There are obviously secondary refuse areas within the compounds proper, indicated by the presence of clusters 2 and 3, which may result from reusing abandoned buildings as secondary refuse areas.

The surveyed area lies in the lowest area of the town. Flows of material (garbage, waste) produced in the town naturally converge here. We might expect that during the life of the town most of the waste ended here and was either deposited in the middens or/and dumped into the river.

The existence of large refuse midden immediate outside the buildup areas of the town are not uncommon around Roman towns. Good evidence for this comes from Rimini (*Ariminium*), on the central Adriatic coast of Italy, where excavations uncovered sizeable deposits of refuse dating to the late Imperial period along the outer face of the town's fortification wall (Gelichi 2000).

All these processes, modified by a series of post-depositional transformations created the observed surface record. Thus different complex processes and palimpsests of these processes can result in the same surface composition, there is always a potential for equifinality.

Remote sensing data (e.g. geophysics) significantly increase the interpretative possibilities. In our case, the information gathered by the magnetometry survey helps enormously in understanding the formation of the deposits and areas of dumping. However, we should not be too eager to directly relate both sets of data. Spatial distribution of artefacts at long-term habitation sites may tell nothing about where other activities besides discard were performed. Interpreting surface distributions in terms of functional activities and thus finding the function of buildings we see on a geophysics map is overly simplistic, especially on such complex sites as *Ammaia*.

Conclusions

We used a multivariate statistical approach and observed the composition of assemblages. In this way, we were able to compare assemblages collected using different methods (non-systematic targeted survey (TS), systematically collected material in regular grids (S1 and S2) and even material collected in shovel pits). However, only the systematically collected material from S1 and S2 (and to a smaller extent SP) can give us spatial patterns of distribution.

Results demonstrate that the abandonment/structural collapse is the main source of variability in surface material. However, within this pattern we can identify assemblages with a slightly higher proportion of pottery and we can even distinguish groups of assemblages with higher proportions of fine ware. We interpret these as the result of secondary refuse.

On complex sites, we cannot assume any direct relation between structural remains and the surface record. This is because the formation of the surface record on complex sites is an extremely complex process or palimpsest of processes.

Artefact survey is, therefore, complementary to remote sensing. Patterns of artefact density on the surface are the result of a series of complex processes and transformations, different from traces of structures detectable using remote sensing techniques. While the geophysical survey produces detailed information on built structures, interpreting surface distributions in terms of functional activities and thus finding the function of buildings we see on maps derived from the interpretation of remote sensing and geophysics is overly simplistic, especially on complex town sites with a long life span.

Dumping activities (because they produce large quantities of material) and abandonment processes are likely sources of major artefact variation, however the effect of functional variation cannot be simply dismissed.

The small-scale surveys at *Ammaia* demonstrated the potential of the survey approach on complex urban sites. The artefact distributions do not simply reveal functional division of the town but should be seen as material residues of long term mundane practices (see Cortese 2005 and 2008). This opens a completely new set of interesting questions. By identifying waste streams through which refuse ends in the surface population, we can address questions of waste disposal, organisation of discard and attitudes towards rubbish. In this way we can see a town as a place of living, of mundane, daily practices and not just as an architectural setting.

PART III

INTERPRETATION AND VISUALISATION

III. 1 THE URBAN SETTING

III.1.A LAYOUT, STREET GRID AND PUBLIC MONUMENTS

C. Corsi

The analysis of the results of the intra-mural geophysical survey (see sections II.5.b–II.5.g), integrated with what is already known thanks to the aerial-photography interpretation (chapter II.3) and the data from excavations (see chapter I.2 with bibliography), has brought to the delineation of the 2D map of the central and lower part of the town, those that were surely built and urbanized, and whose total extent reaches some 16 hectares. As seen above (see II.1-II.2), here the terrain ranges on a slope averaging 6°, and it is therefore suitable for the development of dense urbanized sectors.

This is indeed the first element to stress: as always argued in former contributions (e.g. Vermeulen *et al.* 2005), the "encapsulation" of the hilltop and of its steep slope in the intra-mural area is due to some strategic issues, and the possibility that it was left undeveloped has always been taken into account. We still consider it possible that the steep slope was utilized to install infrastructures like a theatre built with lightweight or perishable material, but the impossibility until now of carrying out geophysical survey in the area has limited our options to answer the questions and our ability to resolve the issue (see also chapter II.4).

The modular town system

Even with the gaps due to the fieldwork limitations (mainly, modern terracing and electromagnetic disturbances: see sections II.5.a and II.5.b) the existence of a regular "chessboard" of blocks of buildings separated by two sets of parallel "empty" stretches orthogonal to each other is quite evident. We can therefore state that *Ammaia* was laid out according to a regular grid, based on at least four NW-SE oriented and declined almost exactly 45°, parallel axes (the so-called *cardines*)[1], crossed by at least eight (possibly nine) orthogonal streets (the so-called *decumani*) (Fig. 88).

The uncertainty about the total number of the *decumani* is due to the fact that the magnetic anomalies nos. 5 and 8 (section II.5.b) in the north-eastern corner of the town have been interpreted as due to the presence of another urban axis, while here, considering its irregular course, it is considered related to a sort of gangway along the wall circuit (paved anyway: see further).

As we saw in section II.5.b, the orthogonal street system organised the town into a total of 44 roughly rectangular building blocks. The dimensions of blocks and the width of interposed streets can vary widely. Street width can reach *c.* 10m (33/34 Roman feet) and even *c.* 11.60m (39 Roman feet) in the two *cardines* flanking the forum (letters "B" and "C"), but it can also "shrink" to only *c.* 2–3m[2], where the big "avenues" are replaced by narrow streets or alleys. Most likely, the width of the paved part should have ranged, even for the biggest axes, around 4m, such as it is attested for the *cardo* in the area of *Porta Sul*.

One interesting feature is located in the extreme northern corner of the town, where the magnetic anomaly no. 13 is interpreted as a paved street flanked by two parallel ditches, *c.* 0.75m wide and more than 7m apart.

The ample range of street widths in *Ammaia* finds some comparisons elsewhere in *Hispania*. Starting from *Mirobriga*[3], via the very dissimilar dimensions of *Italica*[4] and *Augusta Asturica*[5], we get to the broad avenues of *Augusta Emerita*[6] and *Bracara Augusta* (Braga, in northern Portugal)[7].

As seen above (section II.5.b), the interpretation of positive magnetic anomalies led to the conclusion that these streets were paved[8]. Until now, no stretches of preserved

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[1] For matters related to the terminology, see *supra*, section II.5.b.

[2] E.g., between Blocks IX and XIV, XIX and XX, XXVI and XXXI, or XXXII and XXXVII.

[3] Where the street leading to the baths measures 3.35m (Biers 1988: 13).

[4] From the maximum of 8.60m, 8.25m and 8.10m, to the mid sizes of 6.15m and 5.40m to the narrowest alleys of 4.50m>3.55m: Luzon Nogué 1982.

[5] Where on the basis of the study of the drainage network it has been established that urban streets ranged from 4m to 7m or more but it is excluded that they could reach 9 or 10m (Garcías Marcos and Vidal Encinas 1995: 376).

[6] Here all excavated segments of street brought to light until now exceed 5m, corresponding to 17>20 feet, which is sufficient for two-way traffic: Alba Calzado 2001: 402 and 2004b.

[7] Where the street widths range from 10 to 12 feet, with exceptions for the main axes of 25 feet (Martins and Carvalho 2010: 285).

[8] E.g., magnetic anomalies nos. 5, 8, 10, 31, 63, 94, 100, 104, 110, 125, 129, 144, 147, 161, 170, 174.

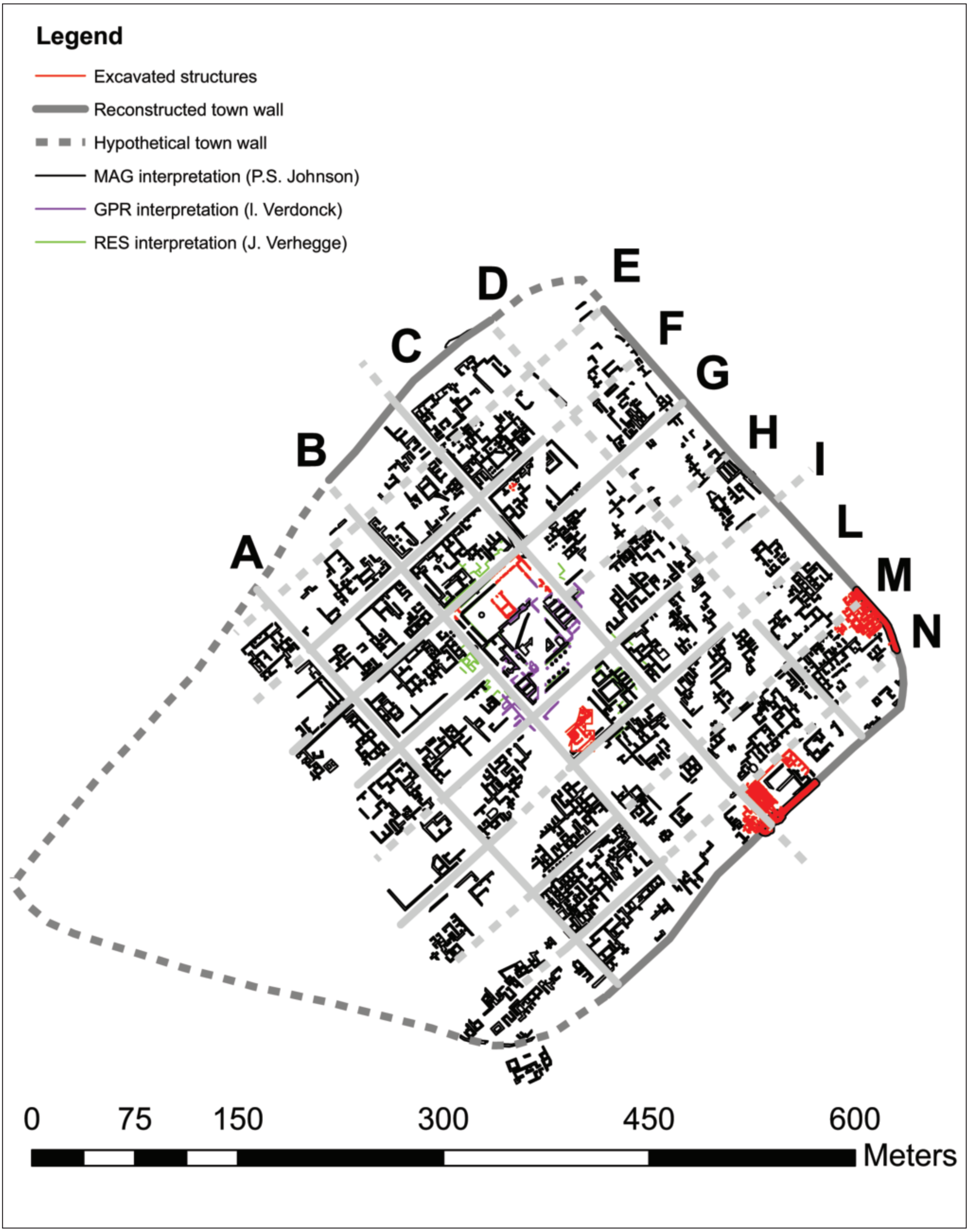

Fig. 88 Map of the excavated areas and of the integrated interpretation of geophysical survey with indication of the schematic layout of the street network (elaboration C. Corsi).

paved streets have been found in *Ammaia*'s excavations[9]: the portion of the *cardo* C along the forum's eastern side and the area in front of the delimiting southern wall of the baths were spoliated (Vermeulen, Corsi and De Dapper 2012: 136; Corsi and Vermeulen 2012), but again on the basis of comparative research we can think about paving with big and middle size blocks or slabs of different stones[10].

Also, in the dimension of the building blocks we register an ample variety: even blocks aligned in the same row (between two *decumani* or between two *cardines*) present different dimensions. Even without taking into account the blocks positioned at the edge of the urbanized area, where the presence of the city walls makes the dimension of the blocks quite irregular, we can note that, for instance, Block XV is *c.* 78m wide and XXXV is almost 80m, while the width of Block VI barely reaches 68m. The distance between the two *cardines* bordering Block X is 76.5m, 35.6m in the orthogonal dimension, while Block XV is longer (40m: see section II.5.c). Block XXII is even longer on the NW-SE oriented side (41m), but it is shorter (74m) on the SW-NE oriented side, even if the dimension on the *cardines'* orientation can be lower (up to 36m: Block XI).

Again, this situation finds many comparisons in Iberia and elsewhere. Here we can just mention the important example of *Italica*[11] where the breadth of the rectangular building lots (here defined as *areae*) which run NW to SE across most of the intramural area, separated by broad NW to SE (*plateae*) and narrow NE to SW (*angiporti*) streets, can vary quite widely.

In the regular grid of *Ammaia*, a certain "hierarchy" among the axes can be noted: undoubtedly the *cardo* connecting the southern gate with the possible gate at the opposite exit (C), flanking the forum on the eastern side, can be classified as a "major" axis. The impression is confirmed by the width and the presence of columns (for porticoes) at least in the northern stretch. The same applies to the *cardo* on the opposite, western side of the forum (B), colonnaded along Blocks X/XI and XV/XVI.

On the contrary, it is not very evident which SW-NE oriented street (the so-called *decumani*) could be classified as "*maximus*". The street running along the southern side of the forum (I), prolonged until the intersection with the eastern wall, can be linked with an extramural road leading towards the river, as it is clearly visible in the results from the extramural geophysical survey (II.5.g). It is axially aligned to what is likely to indicate the location of a gate in the town wall. This *decumanus* is therefore to be interpreted as the primary SE–NW street.

Still, the *decumanus* intersecting the centre of the north-eastern side of the forum, even if it reaches the lower part of the monumental complex, where excavations were not carried out and it is therefore impossible to establish whether there was a direct access to the square, seems to play a major role in the urban scheme. However, as the magnetometry survey has shown the presence in this spot of structures that seem to occlude the transit of the street, we have to conclude that the elements collected thanks to the geoarchaeological survey (Vermeulen *et al.* 2005: sect. 4) have to be referred to a possible gate at the intersection of the *decumanus* I with the wall circuit (see chapter II.4).

On the basis of this analysis and on what was discussed above, we can exclude that the plan of *Ammaia* was organized along two dominant perpendicular streets as is the case with the "planning scheme" of important Roman towns such as the oldest Italic *coloniae optimo iure* but also Augustan important foundations in Italy like *Augusta Taurinorum* and *Augusta Praetoria* (corresponding, respectively, to the Italian cities of Torino and Aosta) (Sommella 1985-87: 105). As stated above, the *cardo* C and the *decumanus* I appear to be the principal streets, but several others (e.g. B, G, M) are characterized by broad widths and embellishments such as porticoes, in a similar fashion. Eventually, the so-called *cardo* C is raised to a central position by the fact that it links the two main suburban roads, the southern starting from the well preserved *Porta Sul*, the northern from a still not identified northern gate (see II.4).

When evaluating the "hierarchy" of the street axes, we surely have to take into account the presence of rows of columns or pillars highlighted by the geophysical survey. They witness the fact that some wider streets were flanked by porticoes at least along a segment of their length[12].

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[9] From the text of Sergio Pereira, it is not possible to understand whether the "ancient road" found under the stratigraphic units 1 and 2 in the several excavated squares of the Parking – lot 1, made with small and medium size blocks of granite, quartzite, schist and pebbles mixed with tile fragments, is Roman or not, as it is attributed to the old (but not ancient!) "Estrada de Calçadinha" and Roman structures were found underneath this road in the square A2. Furthermore, the proposed chronology ("late phase") for this SU 4 is not very accurate and could be placed in the Middle Ages (Pereira 2009: 100-101). It is also still unclear whether this paving constituted only a preparation layer for a paving with bigger stones. Note that in the other lot at the parking area, part of the road is cut into the bedrock outcrop (Pereira 2009: 116).

[10] Diorites, gabbros, amphibolites and quartzite in Merida (Alba Calzado 2001: 402); irregularly shaped quarzite blocks, with small pebbles and tile fragments in between or rougher paving with metalling of pebble and tile fragment in a clay matrix in *Augusta Asturica* (Garcías Marcos and Vidal Encinas 1995: 375-376).

[11] Casa del Planetario: 115.70 by 57.20m; Casa de los Pajaros: 113.90 by 39.10m; Casa del mosaico de Venus: 114.50 by 75.20m: Luzon Nogué 1975: 84-85. It is now clear that the *areae* to the south of the NW to SE road delimiting the south side of the *Traianeum* were closer to being square than rectangular: Rodríguez Hidalgo and Keay 1995: 405; see further.

[12] E,g., the *cardo* B in the portion between Blocks X/XV and XI/XVI, the *cardo* C between Blocks VI and VII and the *decumanus* M between Blocks XXX and XXXV, *cardo* D between Blocks XXXVII and XXXVIII, magnetic anomalies nos. 24, 42, 61, 121, 131, GPR anomalies no. 18 along the *cardo*.

Even if in *Ammaia* we cannot qualify the segments of arcades lining some sides of a few blocks as “colonnaded” or “porticoed” streets, as they are clearly not to be considered a homogeneous set-up of a main street, we can describe these arrangements as partially decorative and partially functional means to add *“decor”* to urban road axes and at the same time to offer comfort to passers-by and shelter for pedestrians. These arcades, in fact, elevate the urban axes to the level of “showpiece streets” and they are a very clear example of how in ancient towns streets were not simply regarded as pathways connecting one place to another. Rather, the function of these covered passageways is to create public space for business and social activities in whatever weather condition (Bejor 1999: 7). Their construction is indicative of the transformation of the concept of the “street” just intended as an open/empty space that marks the difference between built areas, to the idea of the street considered as a monument itself. Substantially, these arcades make you feel as if you are inside a town and not outside a building (Bejor 1999: 112; Kaiser 2011: 14).

The most recent essay on these types of architectural settings along urban streets (in orthogonal and non-orthogonal layouts) has been investigating the Augustan towns of the three Gallic provinces of *Narbonensis*, Aquitania and *Lugdunensis* (Frakes 2009: 83-90). Conclusions claim a certain delay in respect of other types of porticoed spaces, like quadrangular plazas, which appear a main preoccupation of the Princeps’ architects (Frakes 2009: 85-86), but at the same time showing how many variants can be expected in the structural characteristics (e.g. wooden posts atop stone foundation blocks for the earliest phases vs. expensive limestone or granite stucco-covered columns for the later ones) and in the chronological evolution (with some stretches of these porticoes heavily altered and incorporated into the backward properties while other segments were improved (Frakes 2009: 87-88).

As we will detail further (section III.1.b), in *Ammaia*, rows of *tabernae* are often present along the inner sides of these porticoes, as is clearly visible in Block XV.

We cannot evaluate the aesthetic aspects connected with these porticoes such as the typology of the architectural elements (columns, capitals, bases, etc.), nor can we assess which technical solutions were adopted for pavements and drainage, or in which way crossroads were resolved. However, on the basis of comparisons with other Lusitanian towns (see further), for these porticoes we can propose a reconstruction for the first phase with a one-storey single pitched roof, with tiles and roof tiles, supported by rows of granite columns composed of several drums (an earlier phase with wooden installations can be conceived), up to a height of around 3.02m[13] (*c*. 10 Roman feet).

In fact, in several neighbouring Roman towns the presence of porticoes fronting one or more sides of the blocks is well documented, as in *Conimbriga* (Mierse 1999: 85 ss), *Bracara Augusta*, *Iuliobriga* (Alba Calzado 2002a: 383) and *Augusta Emerita*[14], and more examples come from *Baetica* (e.g. *Italica*[15]) and *Tarraconensis* (e.g. *Augusta Asturica*: Garcías Marcos and Vidal Encinas 1995: 377).

It is very interesting to note that in Merida the Augustan urban plan (Alba Calzado 2002a: 374) and in *Italica* the Hadrianic one (Luzon Nogué 1982: 77-89) foresaw in almost all areas, with very few exceptions, the presence of a pedestrian space, usually with a width on each side ranging from 2.5 to 3m[16].

The comparison with Merida can be very useful also to understand the developments following the first implant of the town. Of course, the Spanish town, having been uninterruptedly occupied, presents some very different developments: porticoes here are almost unpreserved because, since Late Imperial times[17], they were incorporated into private dwellings[18].

What is essential to underline here is that some of these transformations, implying also enlargements of the portico’s width and often conversion into enclosed spaces, with the construction of walls between the columns or pillars and

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[13] Taelman 2012: 131-136. The estimation is made on the basis of the Vitruvian proportion suggested for the Doric-Tuscan order of 7 times the diameter, in *Ammaia* ranging from 0.21m to 0.65m, considering that at least the simple top with abacus, echinus and necking should have been present on top. See Alba Calzado 2002a: 378, figs. 9 and 12 for the reconstruction in Merida.

[14] Other examples in the Iberian Peninsula can be found in: *Italica*, *Volubilis*, *Barcino*, *Ampurias*, *Clunia* and *Baelo* (Álvarez Martínez 1981: 234-235; Ruggiu 1995: 280), but only in *Augusta Emerita* the project appears so coherent and extended to almost all blocks, in such a way that it is clearly meant to underline the role of provincial capital.

[15] The case of *Italica* is considered by Bejor (1999: 87) to be a wonderful example of townscape characterized by porticoes, here present on the sides of almost all the blocks of the Hadrianic addition (built between 120 and 130 AD). Luzon Nogué (1975: 88-89) thinks that here the directive of Nero was actually adopted, obliging citizens not only to pave and keep clean the sidewalks bordering their houses, but also to provide them with arcades.

[16] These spaces, once implanted with essential infrastructure such as sewers and road paving, must also have fulfilled a central role during the construction of buildings within the *insulae*, to place scaffolding and machines like cranes, download materials and as working space without hindering the traffic.

[17] The phenomenon started already in the third, but more systematically from the fourth and mainly during the fifth century: Alba Calzado 2001: 409-413 and 2002a: 379-382.

[18] It has been stressed that in *Augusta Emerita* this appropriation is so systematic that it was probably not “abusive” but could rather be considered regulated by the municipal authorities. See Alba Calzado 2002a: 381 for a review of ancient sources about the “management” of these spaces and a possible interpretation of the phenomenon.

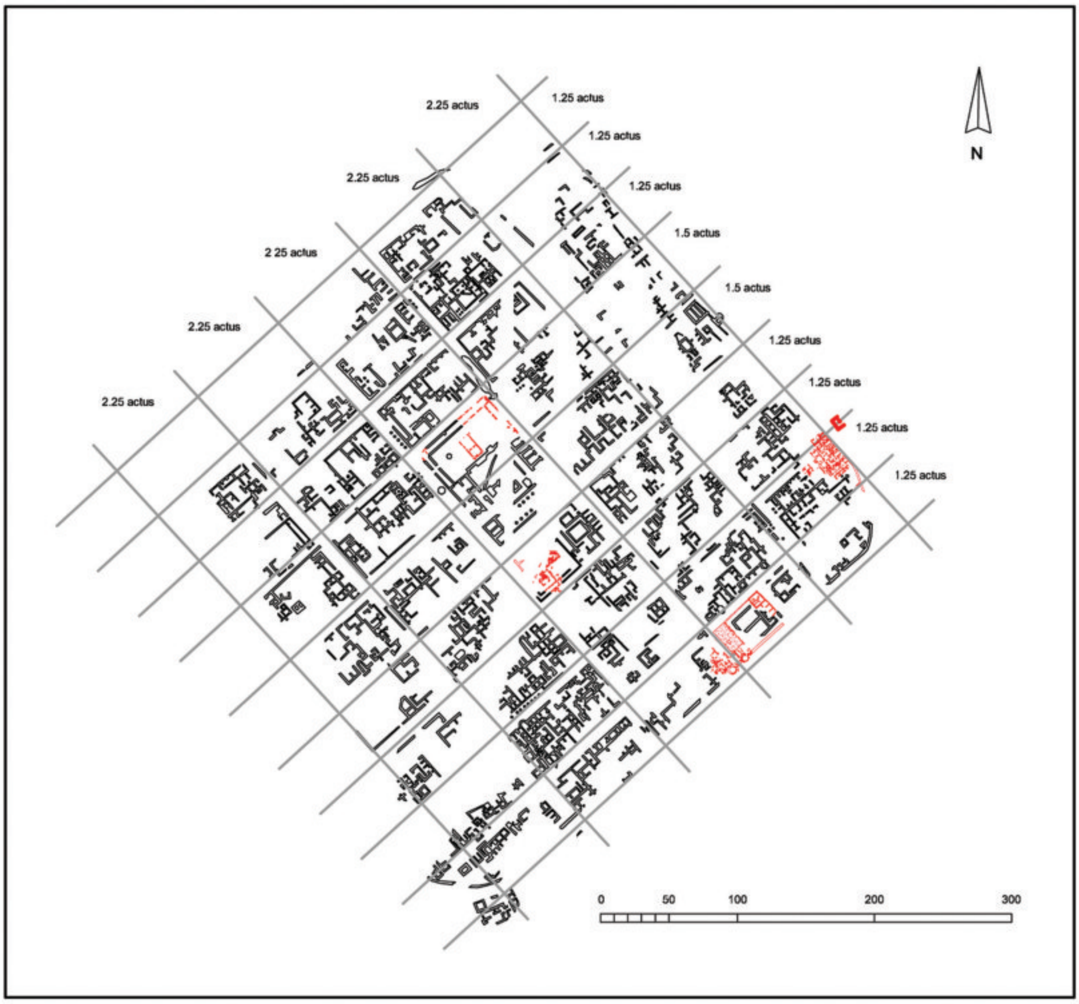

Fig. 89 *Ammaia*: proposed programmatic plan of the town (elaboration F. Carboni).

the infilling of the bays, could have left traces that are partially visible in the geophysical survey. Such is the case of Block XXX, where the stretch of colonnade along the northern side of the street (magnetic anomaly 122) is replaced on the eastern side of the block by an anomaly interpreted as a wall (see magnetic anomaly no. 123). Of course, not knowing the depth of these features, we can even suppose that the wall represents the foundation for the colonnade.

To fully understand the principles of the original project, we were inspired by Sommella's idea of the "programmatic plan" (Sommella 1998: 209-210)[19]. It is essential, in fact to understand that what we see today in the archaeological map of a site, whether this map has been achieved on the basis of traditional excavations or, like here, mainly with non-destructive approaches, does not correspond to the original planning. Instead what we see suffered deformation and subsidence over a long time span, in a way that caused the "consumption" and therefore the "disaggregation" of the original urban planning.

Furthrmore, we have to abandon the preconception that the grids were all perfectly regular and that each block was delineated by streets on each side. It is unequivocally documented elsewhere that even in central areas of the town there were "T" shaped crossroads and some segment of street network were sistematically and programmatically overbuilt (e.g.: Corsi 2012b; Verdonck 2012a).

The *Ammaia* street-grid has been initially tested against an idealized Roman planning scheme of rectangular *insulae* with sides in a proportion of 1:2 or *c*. 45:90m (1¼:2½ Roman *actus*: Corsi, Johnson and Vermeulen 2012), but the first working proposal can be now adjusted in a scheme of 3 rows of blocks in the proportion of 2¼:1¼ at the north-western and south-eastern sides, with two central rows where the length of the blocks along the *cardines* would be higher, in a ratio of 2¼:1½ *actus* (Fig. 89).

If we accept this ideal scheme, we can say that most of *Ammaia's* urban grid was laid out in a proportion not far from 1:2 modules, as is the case of the Augustan foundation of *Bracara Augusta,* with a grid of square blocks of 150 Roman feet (*c*. 1¼ *actus*: Martins and Carvalho 2010: 285). Rather, in the Hispanic provinces, the adoption of square or pseudo-square blocks seems common, as is hypothesized for *Barcino* (*c*. 50 by 40m: Mierse 1999: 79)*, Conimbriga (*Mierse 1999: 85), *Baetulo* (Padrós Martí 1998: 600*)* and *Emporiae* (Mierse 1999: 92).

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[19] A programmatic plan can be defined as a "linear scheme that originally did not have to provide details of street widths, but was based on straight alignments, displayed according to modular intervals, generating an artificial (and only "immaterial") geometric rhythm of the blocks" (Sommella 1998: 214).

Possibly, as in *Ammaia*, in most cases urban layouts implied different modules, both rectangular and square, as is the case of *Emporiae* (with blocks of 35 by 70m corresponding to 1:2 *actus* (Mar 1997: 143), and blocks square and large, averaging 60 to 70m (Mierse 1999: 93), and *Augusta Emerita* (mainly 83 by 66m = 240 by 200 feet, with adaptation in the forum area and in all the *insulae* on the right side of the *decumanus maximus*, where the proportion switches to 4:5 (Mateos Cruz 1994-95: 234).

Intra-mural zoning and movement

On the basis of what has emerged from the integrated interpretation of different types of survey, *Ammaia*, even in the multilayered "radiography" of the still buried archaeological features, appears to be a town where most of the intra-mural surface is occupied by housing sectors, while public spaces are limited in extent. The forum is clearly reserved as a central location, possibly aiming for a high degree of accessibility. The southern neighbouring block is also occupied by the only other identified public complex of the baths (Block XXVI: Corsi and Vermeulen 2012), while what seems unmistakably a sanctuary occupies the relatively close Block XII. Given that the presence of the identified public complexes is so poor, zoning is better expressed by the location of "functional buildings", like warehouses (e.g. eastern sides of Blocks VIII and XIII, Blocks XVIII, XXII, XXXIV and XXXIX) and even better from the location of artisanal sectors outside the city wall (see above II.5.f).

Some preliminary studies of the street network of *Ammaia* with Space Syntax techniques have been attempted (Paliou and Corsi forthcoming). The first interpretation carried out by E. Paliou shows that the NW-SE streets have a high degree of centrality compared to the SW-NE streets. This would suggest that the NW-SE streets were important for channelling movement and transportation through the Roman town (Kaiser 2011: 55-56). This analysis is supported by the fact that these *decumani* are laid out in such a way that they are parallel to the topographic contours[20], so that pedestrian and vehicular traffic was greatly facilitated, while movement along the SW-NE streets that are laid perpendicular to the contours would have been less easy due to the slope.

As anticipated, the geophysical survey has detected features that interrupt, cross or lie under/over the presumed street network[21]. Of course, there are several possible explanations for these "derailments", but they are all connected with the unavoidable difference between the original design and the effective implementation of the urban layout and with the transformations wrought to buildings, both public and private (Corsi, Johnson and Vermeulen 2012: 142-143).

Even if we cannot determine the relative chronologies of these features through the geomagnetic survey, a schematic reconstruction of the settlement dynamics that involved some of the blocks of *Ammaia* is possible via the GPR survey (section II.5.c) and the ground-truthing excavations (Vermeulen, Corsi and De Dapper 2012: 132-136; Corsi and Vermeulen 2012). In this context, the most interesting element comes from the last excavation campaign at the baths (2011). Here it is evident that already at an early stage (the second half of the first century AD?), when the large public complex was overbuilt on existing buildings, a sturdy terracing wall for the construction of a platform overcame the southern edge of the block, projecting into the street. This phenomenon must have been very normal when there was the necessity to insert larger complexes into the urban layout. Other cases are related more to later phenomena of "appropriation" by private entities of public spaces, in such a way that they generated encroachment. For instance, the presence of apsidal or rectilinear structures encroaching upon the roadway[22] can be related to Late Imperial transformations of upper class *domus* (Corsi, Johnson and Vermeulen 2012) or to misappropriation of public spaces[23]. As stated above, most of these phenomena are typical of later phases. In Merida, where the evolution of the urban layout has been carefully reconstructed, it has been proved that the limits of the scheme were respected until the second century AD, with regular blocks of homogeneous dimensions separated by streets of uniform width (Alba Calzado 2002b: 135, and 2004a: 72). While transformation during the second and the first part of the third century almost exclusively implied the elevation of public and private build-

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[20] This is more apparent at the NW where there is less evidence of human intervention (e.g. terracing) in the landscape after the Roman era.

[21] See, e.g., magnetic anomaly no. 73 (Block XVIII), constituted by a series of rooms displayed on both sides of a "spine" NW-SE oriented wall, which seems to block the *decumanus* H.

[22] E.g. magnetic anomalies 17, 25, 70, 93, 108, 114, 128, 132, 148, GPR survey: Block X, along d*ecumanus*.

[23] In a few cases, the interpretation of the buried features is not certain, so we cannot establish whether these anomalies have to be considered as structures encroaching on the street or part of the drainage and sewer system: e.g. magnetic anomaly no. 78.

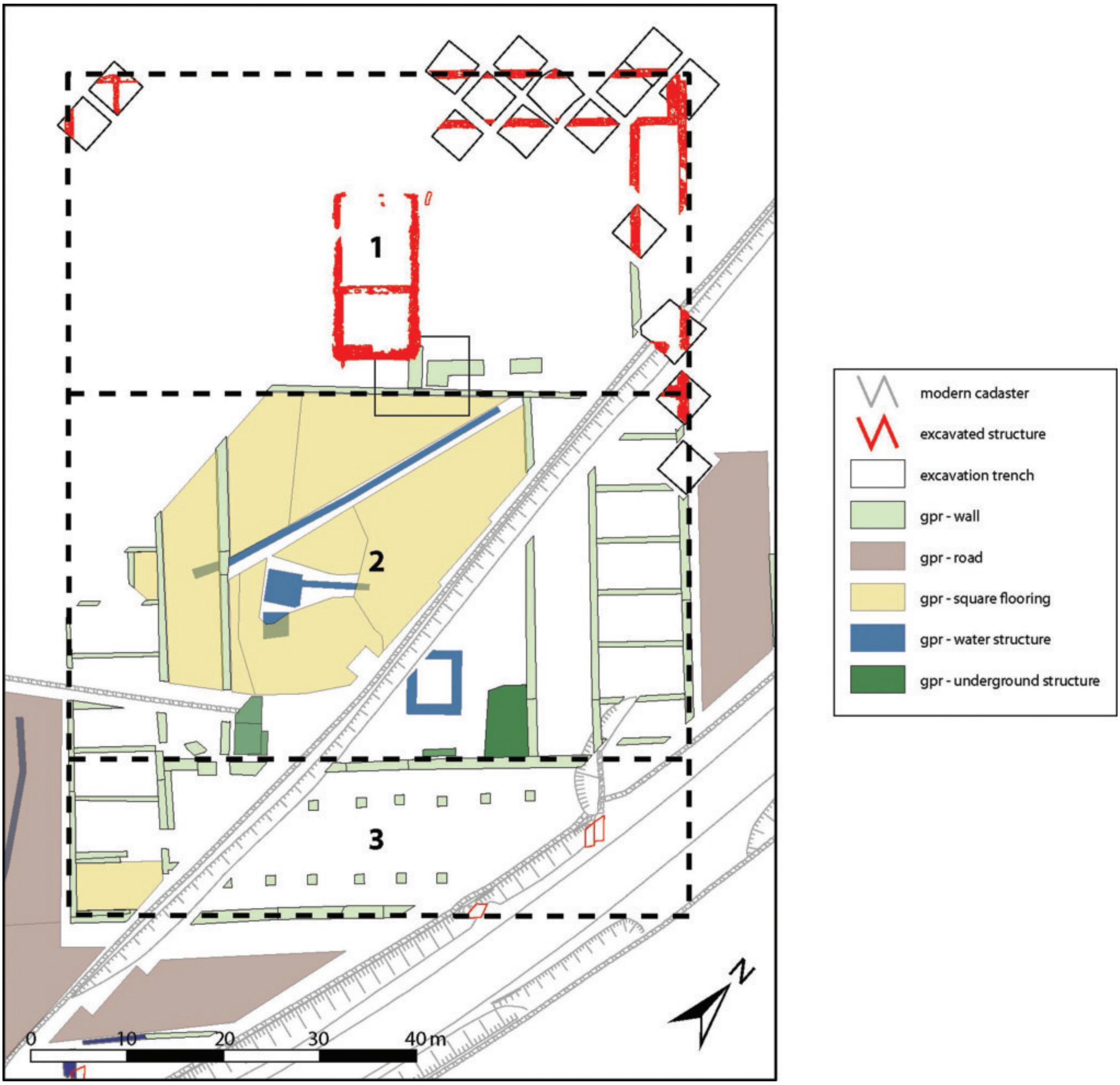

Fig. 90 Interpretation of the forum based on merging the data from excavations and GPR interpretation (elaboration by D. Taelman and L. Verdonck).

ings up to a second floor, from the end of the third through the fourth and the fifth century in Merida we can identify phenomena of encroachment of streets, which are reduced to only 5m in width, mainly due to the "horizontal expansion" of mansions (Alba Calzado 2004a: 75). From the fifth century onward, we see a typical process of rubble disposal, even in the central area of towns, with the consequent disintegration of the definition of built and open spaces.

In *Ammaia*, the "disrespect" for the urban grid layout is mostly visible in the areas at the edge of the intra-mural surface, next to the walls. Most of the times, the shape of these plots is irregular, like "cut-outs" of some sort. They are expected to be left unbuilt[24] or eventually used for functional buildings (casemates, garrisons, storage rooms and warehouses, etc.). Still it is very frequent in Roman towns that some buildings, whose function is not always clear, are huddled up close to the walls. In *Ammaia*, in at least one case we can see that later buildings leaned against the wall itself on its external side (Pereira 2009: 121). In Orange, a rescript by Vespasian proves that those who have illegally occupied

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[24] For instance, in *Barcino*, a broad alley of 7.30m separates the city walls from the existing buildings; it is therefore possible that this "ring" marked the ancient *pomerium*: Mierse 1999: 81.

the plots next to the walls are condemned to pay a fee proportional to the area illegally occupied (Magdinier and Thollard 1987: 94). In any case, it is surprising to see that these buildings do not respect the orientation of the walls, and this can be explained mainly by the different moments of the construction of the wall and the urbanization of these areas.
The case of *Ammaia*, though with uncertainties arising from the lack of stratigraphical information and the impossibility of drafting the diachronical evolution of the bi-dimensional map that we achieved by integrating different types of survey, sheds light on the process of the making of an urban plan, mainly thanks to the comparison with similar cases. In *Augusta Emerita*, for instance, it has been established that the streets were not paved soon but, even if drawn so as to delimitate the blocks, they were left as dirt roads (Alba Calzado 2001: 402-403). Streets were paved in Merida only after the first decades of the first century AD, after the drainage and sewerage systems were constructed (Alba Calzado 2001: 417-418).

It is likely that the layout of *Ammaia* was from the beginning conceived as a regular orthogonal plan[25]. A very few segments of buildings with different orientation have been detected in one sector of the southern gate excavation area (Pereira 2009: 60-68), but they are so few as to be negligible, and can eventually be rather attributed to later phases than to the early settlement. Astonishingly, this orientation has been respected also by the eighteenth century farm that now houses the on-site museum (called Quinta do Deão).

The fact that the street-grid of *Ammaia* as identified through the geophysical survey, and therefore to be considered chronologically compressed, diverges significantly from any ideal scheme, has to be considered a confirmation that through the “radiography” of the subsoil we can “see” the palimpsest of occupation and transformations over the centuries following the initial planning.

Public monuments and open areas

The observation that the forum has to be considered as the core of Roman urban settlements is undoubtedly true in *Ammaia*, where, at this stage of research, not many other public complexes have been found (see, *supra*). In the forum, in fact, all the symbols and buildings which embody the municipal status are grouped with the religious, commercial and administrative structures, and they qualitatively mark the townscape (Gros 2001: 376).

Thanks to the geophysical survey, the forum of *Ammaia* is now rather well-known in its plan and in its relationship with the urban layout. When considered only in 2D, it is very clear that the central position was meant to facilitate accessibility, as is the case in most Roman towns (Gros 2001: 377).

The recent research, focused on the reconstruction of the topographical settings of the area (chapter II.2), and on the understanding of the volumetric outwards of the complex, has been able to shed light also on some more technical features of the project and on how challenging some architectural solutions have been to overcome the morphological constraints. Even if in *Ammaia* the orographic features do not reach the complexity of neighbouring sites like *Aeminum* (Carvalho 1998; Alarcão *et al*. 2009), some measures still had to be taken to create a levelled platform for the square. The platform was supported on the NE corner and along the eastern and southern sides by inclined galleries, which at the SE corner reached the maximum height above ground (Vermeulen, Corsi and De Dapper 2012: 136; see: II.5.e and III.3).

The forum complex, which measures 88 by 65m, occupies two blocks of the urban grid (Fig. 90). As noted above (section II.1.a), the width of the terracing is lower than that of the neighbouring blocks, in such a way that the two *cardines* which run on the long sides are wider. This small restriction of the dimensions of the platform could also be due to the need to adapt to the technical and economic resources available to the project. The plan of the forum, as reconstructed on the basis of geophysical prospections and limited excavation, can easily be ascribed to the well-spread type named “tripartite forum” or “forum block” (Ward-Perkins 1970: 1-19), which is also called a “double”- or “compound-forum”. It is in fact characterized by the combination of three sectors with different functions: a temple or an *aedes*, often raised on a platform; a central courtyard; and a basilica hall (Gros 1996: 212-213). The sacred part of the *Ammaia* forum was dominated by what could probably be interpreted as a *capitolium*-type temple. The latter was erected on a podium, still standing above ground and preserved to a height of around 2.50m; it measures 9 by 17.30m. The temple, as proved by the two ground-truthing excavation campaigns carried out in 2010 and 2011[26], was equipped with a monumental staircase on its short southeastern side, directed towards the square. Its entrance way was probably flanked by symmetrically placed water basins.

What has been proved by the ground-truthing excavation campaigns of 2010 and 2011 is that the “sacred” part of the complex was not raised on a platform, as is documented in other comparable monuments. In fact the pavement of the square in granite blocks, similar to those used in the square next to the south gate, was situated at the same level of the lowest step of the temple staircase, and that the area around and behind the temple possibly had only a beaten earth flooring mixed with small stones[27]. The very well visible anomaly interpreted in the geomagnetic survey as a delimiting wall supporting the higher platform on which the temple would have dominated the square, has been in fact related to the structures that flanked the podium of the temple and to the disruption caused by the monumental staircase (see II.5.b-c, II.5.e).

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[25] This fully contradicts certain unfounded recent observations (Osland 2006: 57) that *Ammaia* was initially an indigenous settlement but seems to have undergone extensive re-organisation in the early first century AD.

[26] As anticipated in the introduction, the results of the excavations will be the subject of volume II of this series.

The centrally and axially positioned temple was surrounded on three sides by a portico, which on the northeastern side was built above an active but low cryptoportico (Vermeulen, Corsi and De Dapper 2012).

The very symmetrical central square of the forum measures some 53.5 by 31m. It is surrounded by a 6m wide inwards oriented portico fronting on either side 7 rows of rectangular "rooms" with dimensions around 8.9 by 4.9m. The latter are probably predominantly *tabernae* and some of those on the eastern side (which is not excluded to be two-stored at least in the portion next to the basilica) are surely facing out towards the streets. A keystone of an arched structure found near the most northern "room" indicates that this could have been one of the lateral entrances to the forum complex. The geophysical surveys indicated the presence of a whole series of mostly rectangular structures positioned on this forum square. They could possibly indicate different podia, statue bases and even cisterns. One linear diagonal feature is most probably the aqueduct leading to one of the water basins.

On the opposite site of the square from the temple was the basilica, which fits into the original model, basically a rectangle where proportions can vary, but of a length at least two times greater than the width, and with an internal colonnade that surrounds a long, narrow space, around which runs an ambulatory (Gros 2001: 275-276). The basilica of *Ammaia*, an elongated rectangular building measuring some 46 by 17m, was characterized by a double row of internal roof-supporting columns (Vermeulen, Corsi and De Dapper 2012: 129), spaced at about every 4m. The naves were perhaps unequal in width and the central aisle was around 7m wide. Its entrance is probably located centrally in its northern long side.

On the short south-western side the three-aisled building was flanked by three elongated rooms, whose function is still unknown, but it is believed that they were linked with the administrative functions of the building (Vermeulen, Corsi and De Dapper 2012: 129).

There is also comparative evidence to possibly interpret some of these rooms as devoted to the imperial cult. The interpretation of at least one of them as *Augusteum* may be supported by the inscription of the local *flamen* G. Iulius Vegetus (*CIL* II 160 = IRCP 617), as these priests were sometimes connected with deified emperors (Stylow 2009).

The preliminary study of the archaeological finds points to the mid-first century AD (possibly the reign of Claudius) for the beginning of the construction, with an early phase of renovation probably undertaken in Flavian times (the last quarter of the first century AD) (Vermeulen, Corsi and De Dapper 2012: 131). Planimetrical and chronological comparisons can be found in *Lusitania* (*Augusta Emerita, Ebora Liberalitas Iulia*, *Pax Iulia*, *Sellium* and Bobadela: Persichini 2012) and in the wider context of the other Hispanic provinces.

We have already drawn attention to the absence of other large public complexes, with the exception of the baths, in the Block south to the forum (Fig. 92). This possible public structure occupied only the western half of the building block south of the forum, while the eastern part was taken in by a large *domus*. The integration between the data from archaeological excavations, which indicate part of a bath installation (*calidarium* or *tepidarium*), a corner of a big *natatio* and portions of other rooms (see Corsi and Vermeulen 2012), and the geophysical, and mainly the GPR survey, has made it possible to propose a hypothetical reconstruction (section II.5.c and chapter III.3). It is an almost square building of some 40m side and its dual angular planning with linear bath sequence and a partly open air *palaestra* with portico and swimming pool show many similarities with other bath-houses in *Lusitania*, such as the excavated Flavian Termas da Muralha in *Conimbriga* (Reis 2004) or in *Hispania*, such as in *Arcobriga* (Fernandez Ochoa, Morillo Cerdan and Zarzalejos Prieto 2000: 64). The baths of *Ammaia* were fully active between Flavian times and the end of the second century, but the building stayed in use until the fourth century.

Segments of the thick walls of the *natatio* are in fact still visible not only in the talus of the modern road N359, but also under the pavement (GPR anomalies nos. 3, 5, 6) and even part of its floor (GPR anomalies 8 and 9), while the "corridor" or portico surrounding the swimming pool, documented in the excavated sector, is proved to continue also on the northwest and southwest sides. The entrance of the complex is hypothesized on the *decumanus* to the north (letter I).

At the moment the number of identified other public buildings and monuments in *Ammaia* remains limited. Another possible thermal complex can be identified in Block XXXV, but this needs confirmation.

It is undoubtedly remarkable that at this stage of research no traces of a theatre or amphitheatre have been identified. As such large infrastructures could not be hidden in the "gaps" of the survey, few explanations are still possible. Apart from the possible location of a theatre built with lightweight or perishable material on the intramural slope of the Malhadais hill, spectacle buildings might be placed outside the walls, even if in Iberia most of the many theatres identified by archaeological or textual evidence are inside the walls and the suburban position is quite exceptional (Ciancio Rossetto and Pisani Sartorio 1997: 188-191).

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[27] This is an important anticipation on what will be published in the final edition of the excavations (the already mentioned volume *Ammaia* II). Some preliminary data can be found in Vermeulen, Corsi and De Dapper 2012 and in Persichini 2012.

Religious complexes surely identified are also very limited. However, the sanctuary in Block XII is quite large (around 35 by 25m) and very characteristic, with a temple (*c.* 6 by 7.5m) that seems to be placed on a wide platform (*c.* 16.5 by 11m, see: II.5.b, no. 50), surrounded by a *temenos* (II.5.b, no. 49).

Another anomaly that could be interpreted as part of a public monument or infrastructure is the magnetic anomaly no. 55, in Block XIV, considering the peculiar plan that can be reconstructed on the basis of the geophysical data interpretation and, most of all, the remarkable thickness of its walls (see section II.5.b).

With these few exceptions, the intra-mural surface of *Ammaia* appears to be entirely taken up by housing or commercial buildings.

Commercial buildings

The presence of separated rectangular rooms that open onto the street, which can be interpreted as shops or handcraft ateliers, is individuated in almost every block, but they seem to be distributed unevenly, with clustering along the two main *decumani* "B" and "C"[28]. These rows of rooms, which clearly qualify as *tabernae*[29], can be interpreted as "bazaar" sectors, qualifying those *cardines*, or at least those stretches of urban axes, as "commercial streets". These sectors are expected to have been bustling with people, noisy and dusty. Maybe it is not a coincidence that Blocks VII, IX, XI, XII, XV, XXII, clearly occupied by housing complexes, are not open onto the *cardines* but onto the *decumani*[30]. A possible interpretation of this concentration of shops is that here, along the main *cardines* and mainly in the area surrounding the forum, most commercial activities took place, while in the other sectors possibly only basic trades were carried on, for essential services.

Considering that the space available in the forum square was not huge (no more than 1000m^2), and that the central location, however accessible, could have made it difficult to bring in heavy or bulky goods, it is possible that some other areas in town were used as markets. In this sense, the open space at the back of the southern gate must have been ideal for a market and trades, including herds and animal droves.

Another possibility is in Block XVII, where the magnetometry survey has revealed the existence of an open courtyard or square with some evidence of a colonnade, open towards the *cardo* to the SW (magnetic anomaly no. 65), which could be interpreted as a kind of *macellum*.

Finally, an essential part of the detectable urban infrastructures was, obviously, constituted by the drainage, sewers and water provisioning systems. About the latter, we will see further how we can reconstruct part of the path of the western aqueduct inside the town (chapter III.2). Anomalies identified through the geomagnetic and the GPR surveys can be interpreted with a high degree of likelihood as part of the drainage system of the city. They often appear to border the urban axes, a very common phenomenon in most Roman towns in the Iberian Peninsula and beyond (Remola Vallverdu and Acero Perez 2011)[31].

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[28] Such is the case of the anomalies individuated in the magnetic survey nos. 41, 61, 135 along *cardo* B, and 4, 24, 86, 109 along *cardo* C.

[29] Apart from the above-mentioned, we can still list magnetic anomalies nos. 91 and 107.-

[30] One exception is Block XXVII, with anomaly 112.

[31] E.g., GPR anomalies no. 20 underneath the *cardo* and 22 under the *decumanus*; Block XV no. 35, under *decumanus*.

III.1.B HOUSING

C. Corsi, F. Vermeulen

Introduction

Twenty years after the complaints by Beltrán Lloris that the study of domestic dwellings in *Hispania* was still very incomplete (Beltrán Lloris 1991: 8-9)[1], we can observe with satisfaction that in *Ammaia* many data were acquired and processed, which can help to move forward the knowledge about Roman housing in this western provincial context. The strength of an approach with intensive geophysics as applied here in *Ammaia*, lies in producing a "big picture" of domestic dwellings in an urban context, which allows to frame better the more detailed information obtained from house excavations in this and other neighboring sites. At the same time, again with Beltrán Lloris (1991: 7), we can be satisfied with the fact that many Romano-Iberian houses have in recent years been published as "contexts", and that data about structures, decorative apparatus, materials, tools and hardware have been linked to each other, so that we obtain a better understanding of the related economic, social and structural aspects of living in a town. However, we have to admit that, in spite of the large number of useful monographic studies and some syntheses (e.g. Balil 1972; Alarcão and Étienne 1977; Beltrán Lloris 1991; Fernández Vega 1999; Uribe Agudo 2008) many uncertainties still persist about Roman housing in the Iberian provinces. Often, we are faced with house types that cannot be fully inserted in the classical Mediterranean model of "*domus* with *atrium* and/or with *peristylium*", and not many data have been collected concerning the commoner residences. More research is needed to identify and contextualize the different types of Roman houses in Iberia, examining their different organic parts and highlighting their specific formal, constructive and functional characteristics. As private urban architecture in the provinces is often the result of regional adaptation of imported Italic models we need to keep an open mind to different forms and constructive solutions, especially as a particular Roman town can now be considered as a whole and in all its diversity. We need to stress that the "uniform and unitary vision" of the Roman house as it is so well attested in *Pompeii* and *Herculaneum*, has been scattered into a variety of possibilities, depending on the geographical, but also social factors. In fact, the planimetric organization of dwellings does not correspond to rigid and stereotyped patterns as we are often led to believe, but instead there is always adaptation on the basis of climatic elements, the topography of the site, building traditions, availability of space and many other variables. Furthermore, we have to take into account how limited sometimes our knowledge is of the complex history of most of these buildings, even when excavated, because these housing complexes are located in centres with continuity or because in most cases it is impossible to investigate the earliest phases.

Organisation of housing in *Ammaia*

The excavations achieved between 1999 and 2001 by the archaeologists of the *Fundação Cidade de Ammaia*, underneath the structures of the *Quinta do Deão*, the historical farm house that nowadays hosts the local museum (see chapter I.2), have provided some information about the seriation of important transformations that affected this eastern sector of the town and have supplied some basic data about building and veneering techniques (Pereira 2009: 77-98). However, the comprehension of the whole dynamic of evolution is still incomplete, and in any case, we cannot extend these local and peripheral processes to other portions of the town. Other (poor) data about building techniques for private buildings come from the excavation of the baths near the forum, where some early structures, interpreted as part of houses built during the first phase of the town development, were later incorporated into the thermal complex (Corsi and Vermeulen 2012). The fragmentary state of these finds does not allow much interpretation and this applies also to a few remains of early first century houses excavated in the later monumentalized sector of *Porta Sul* (Pereira 2009: 60-77).

However, as was demonstrated above, it is essentially thanks to the new survey data that we can now really understand something of domestic architecture in this town. Before going into the urban residences and housing sectors of *Ammaia*, as they appear on the basis of survey data (Fig. 91), it is essential to point out that mainly the data from the geomagnetic survey are "flattened" in a 2-dimensional map,

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[1] An exception for the early years are the numerous publications by A. Balil devoted to the *Casa y urbanismo en la España Romana*, edited in the journal "Studia Archaeologica – Universidad Santiago de Compostela", 17-18, 20, 28 (1971-1974).

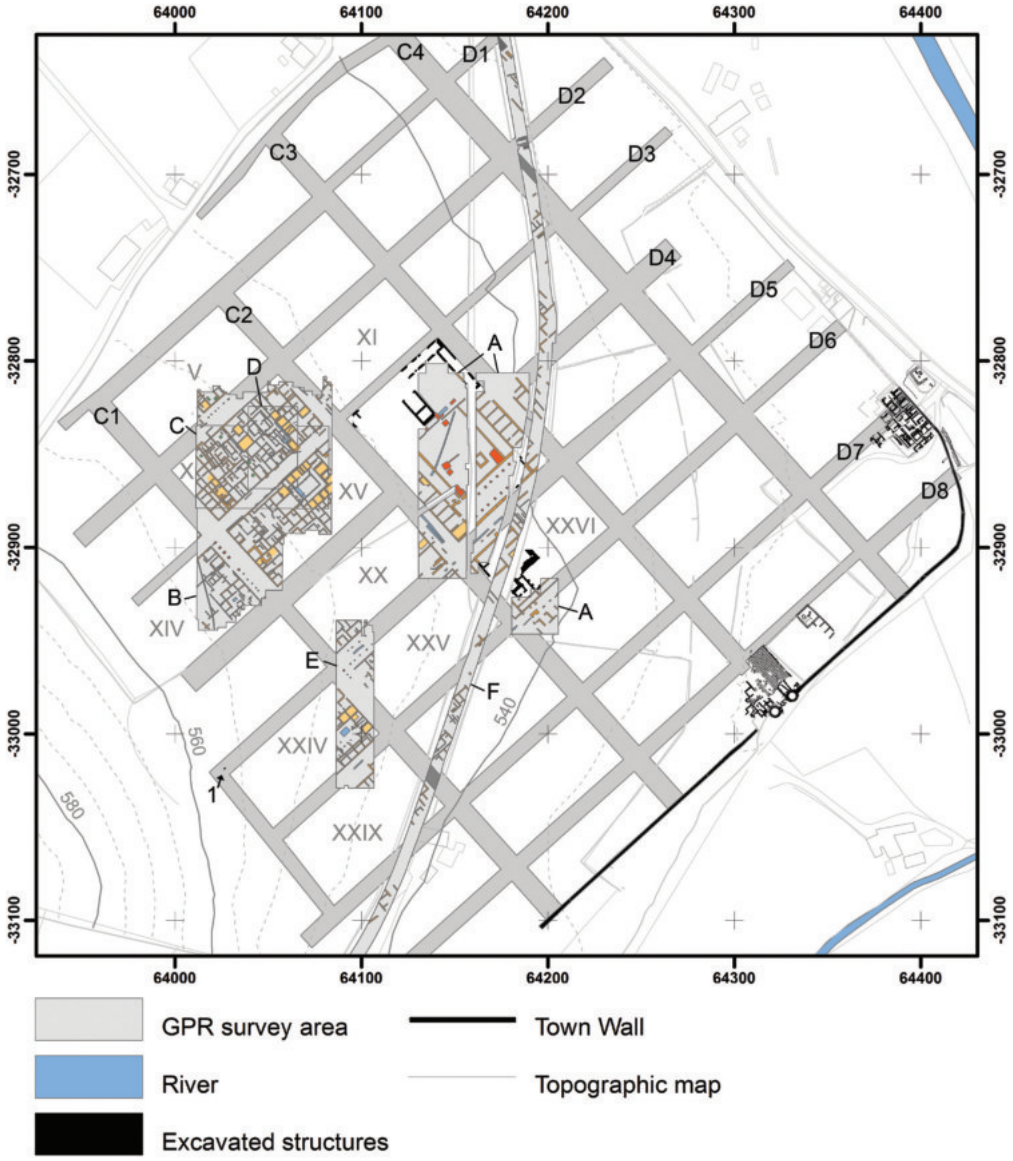

Fig. 91 Location of sectors where houses were studied in detail. Apart from the partially excavated houses near the southern gate (*Porta Sul*) and the eastern corner of the town, most plans are derived from GPR surveys south and west of the forum denoted by A to F) (elaboration L. Verdonck).

which combines all the transformations that have affected these buildings often during several centuries of occupation. This hinders much the interpretation of house plans, even if some areas are less affected by such transformations than others. Nevertheless, in some cases, mostly the 3-dimensional information collected by means of GPR survey, integrated with some focused stratigraphic ground-truthing and higher resolution earth resistance survey, have allowed the definition of a certain phasing in the transformation of urban houses (Corsi 2012b; Verdonck 2012b). Still, a final interpretation based mostly on geophysical data, remains impossible even though GPR survey has in different sectors been able not only to distinguish easily all essential walls, floors and even columns, but also other meaningful linear structures, such as local aqueducts or drainage systems, and the associated basins, fountains, *impluvia* or cisterns, and sometimes even ovens, cooking installations and hypocausts.

As noted above (III.1.a), most blocks of the urban grid seem to be partly or sometimes fully occupied by housing complexes, even if also commercial and artisanal functions (*tabernae*, workshops, etc.) are present in many *insulae* where some are no doubt directly associated with the domestic functions. This observation allows us to estimate that more than 80 % of the available space in the built up part of the intra-mural city is made up of houses and some associated structures. We must immediately stress two factors here, of some importance in the evaluation of the space really taken in for domestic activities.

First, it is not clear how many of the possible *tabernae* that can be distinguished along several main streets also had a function for housing families or individuals. Even with careful excavation that nut is hard to crack. But today it is generally assumed that this type of construction refers to a partially habitable room, located on the ground floor and open to the street, which serves as a small workshop and/or for local sales. Often it has a mezzanine used for storage but also as the residence of the *tabernarius* and his family (Rosada 2001).

Secondly, when considering the general ratio between built and open spaces, we have to recall what was already stressed in the methodological introduction to the geophysical survey (see section II.5.a): some of the "gaps" in our 2-dimensional synchronic map are surely due to casualty, extemporaneous factors and modern disturbances, but we do not have to neglect the fact that ancient towns, like modern ones, knew the presence of open areas, and that housing blocks, in Antiquity much more than in contemporary architectures, included open spaces like gardens and courtyards used for a variety of activities.

In most, if not all cases the regular building blocks of the orthogonal town system are clearly fragmented in several house units, while a few *insulae* are for a large part occupied by just one vast *domus.* At the moment we cannot identify an *insula* that is fully taken in by one house only, but then again the data do not allow for a definitive judgment. In certain cases, as in Block XX, we observe the presence of features which carefully divide the block in two parts, oriented along the short NW-SE axis. This is also clearly visible in the *insula* directly south of the forum, where a big house shares the plot with the forum baths. In other cases, like in Blocks X and XV, a kind of "spine" wall is visible lengthways the main NE-SW axis over practically the whole block. It therefore divides the *insulae* in two equal longitudinal halves, allowing for further subdivision in semi-regular plots.

When detectable with enough detail, most houses seem to give direct access to the *decumani*. These streets follow the slope of the hillside on which the town was built, and therefore the house entrances appear to be more secluded to busy traffic and circulation (see section III.1.a). But exceptions are recorded: such is the case of the wide rooms or open spaces at the centre of Block X, where the access is almost certainly from the *cardo* flanking the eastern side of the block, or in Block XIV, where the opening of the cluster of rooms seems to be on *cardo* A which, as it possibly marks the limit of the urbanized area toward the steep intra-mural slope, is anyway to be considered a "very quiet" street.

House typology

In general terms we observe that the interpretation and data fusion applied to the results of the different geophysical surveys indicate that housing in *Ammaia* reflects at least two different levels of status, but only further indepth investigation via stratigraphic excavations will be able to clarify whether some houses, not only had a more elaborate plan and larger dimensions, but were also adorned with other indications of status such as mosaics and richly painted walls.

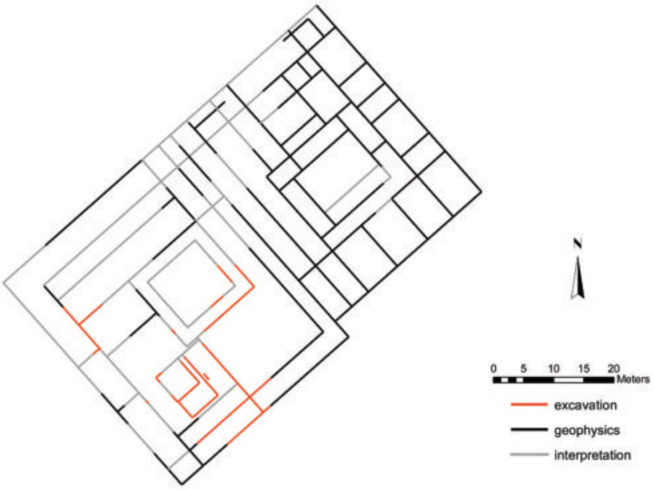

Fig. 92 *Insula* south of the forum with bath complex (left) and *domus* (right) based on integration of excavation and survey data (elaboration D. Taelman).

A limited series of houses clearly belongs to the type of higher status dwellings we expect to find in many full grown Roman towns, although their sizes are not as extreme as in some Mediterranean cities. At present we could identify only five or six of these large *domus*, but their number could certainly be higher[2]. In all of them there seems to be evidence for the presence of a colonnaded courtyard*,* whose dimensions may vary. This architectural feature, mostly if combined with other elements such as the spaciousness of the rooms, leads us to classify these complexes as "upper class mansions", much influenced by Italic prototypes and widely available in the Roman towns of the western Mediterranean area. Remarkably, most of these *domus* in *Ammaia* seem to be located close to the forum and they fronted those urban axes appearing to be "preferential" in the town grid (see section III.1.a).

For three of them we obtained a quite reliable and detailed plan, using combinations of geophysical techniques. The first is the house which in Block XXVI shares the space within the *insula* of the baths and thus profited from a prime position in the centre of town. According to the results from combined earth resistance and geomagnetic surveys (see section II.5.e) it is a rectangular house of some 43 by 30m (circa 1290m²) oriented with its eastern long side towards the *cardo maximus*. Here it is probably bordered by a series of *tabernae* opening up to this main street. The location of the house entrance is still unsure, but the

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[2] These houses seem surely to be present in Blocks XII, XV, XXII and XXIV. Some other good options are Blocks VI, VII and XVII.

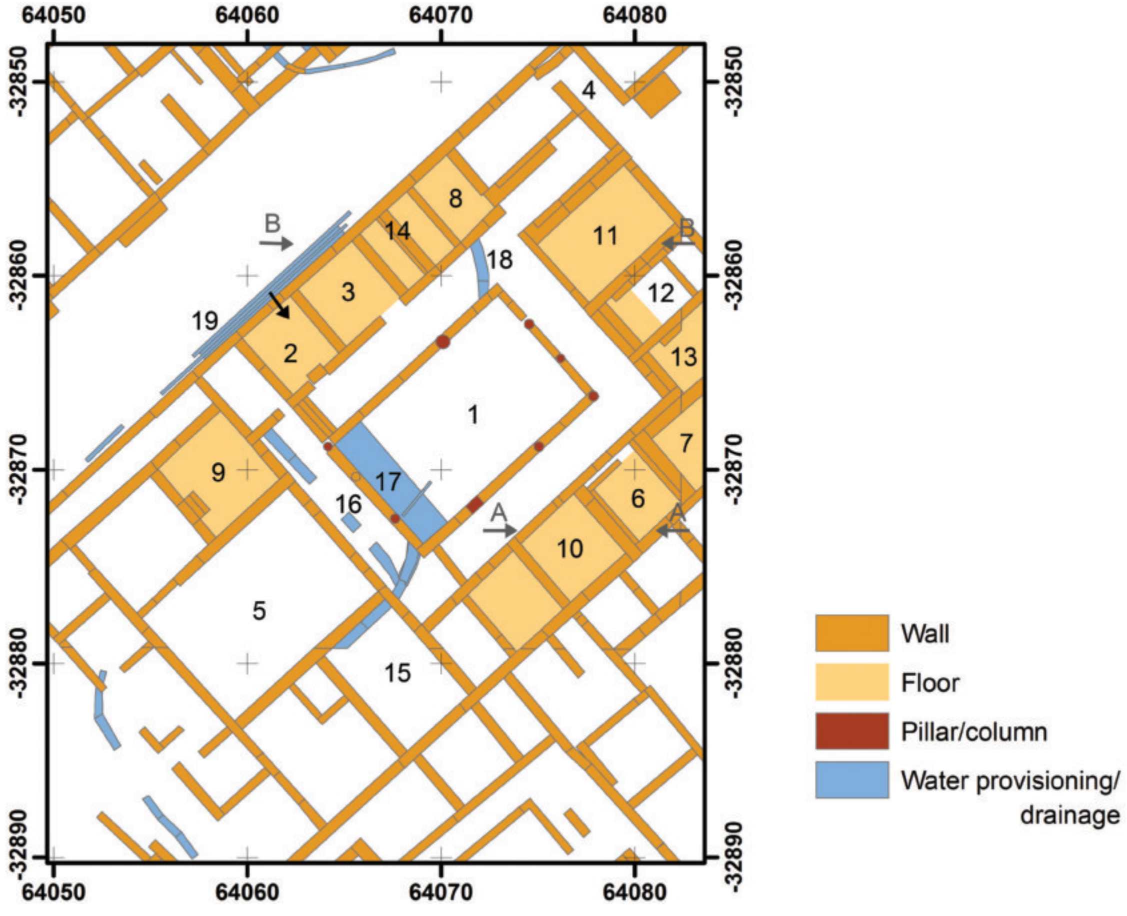

Fig. 93 Archaeological interpretation of the GPR survey results over a large peristyle house in *insula* XV. Rooms are organized around the *peristylium* (1) and a large *triclinium* (5) dominates the central axis (elaboration L. Verdonck).

whole building is centered on a large courtyard, probably of the peristyle type. This open space is surrounded by several large rooms, some of which probably still have their flooring preserved. The survey data indicate a well built regular house suffering no apparent major alterations through time. Maybe it was contemporary with its immediate neighbor in the same *insula,* a house originally built in the first half of the first century, but later in Flavian times replaced by the monumental baths and therefore ill preserved (Quaresma 2010-2011; Corsi and Vermeulen 2012).

A second house, found in Block XV in an evenly prime location immediately west of the forum, was studied with high resolution GPR survey (II.5.c, Fig. 93). The building block is divided in two unequal longitudinal parts and a large share of the northwestern half of the *insula* is taken in by this *peristylium* house covering a surface of circa 35 by 23m (805m²). Here the potential for data interpretation is so high, that we can figure out the spatial organization of the rooms displayed all around the colonnaded *peristylium*, a circa 12 by 7.5m large area enclosed by twelve columns and surrounded by a circa 2.5m wide corridor. This central garden displays features of a large underground cistern in its western part. Some surrounding rooms were probably just *cubicula* while the main and large *triclinium* (circa 8.25 by 10.75m) lies in the same axis of the peristyle space. Among the properly floored rooms around the *peristylium* some were interpreted as having cooking functions, others on the eastern side might have been used as private baths with a *hypocaustum*. Internal steps indicate how these houses, built with their long axis along the orientation of the slope, adapted internally to the topography of the site (Verdonck 2012b: 176). The house shows some minor alterations in its construction suggesting at least two building phases.

A third large *domus* was built near the eastern corner of Block XXIV, at greater distance from the forum, but along a broad *cardo* with many porticoes (Fig. 94). It was interpreted by combining earth resistance and GPR survey data. The rectangular house measures some 34 by 21m (circa 714m²). It was probably centrally entered on the short side along the *cardo*, through the *fauces*. A series of rooms, most with reflexions of still existing floors, is quite symmetrically organised around a large central *peristylium* with colonnade and cistern. In the central axis, on the opposite side of the garden a larger room indicates the presence of a visualy dominant *triclinium*. As in many parts of *Ammaia*, there are features pointing to different building phases, but no major transformations are noted (Verdonck 2012b: 187).

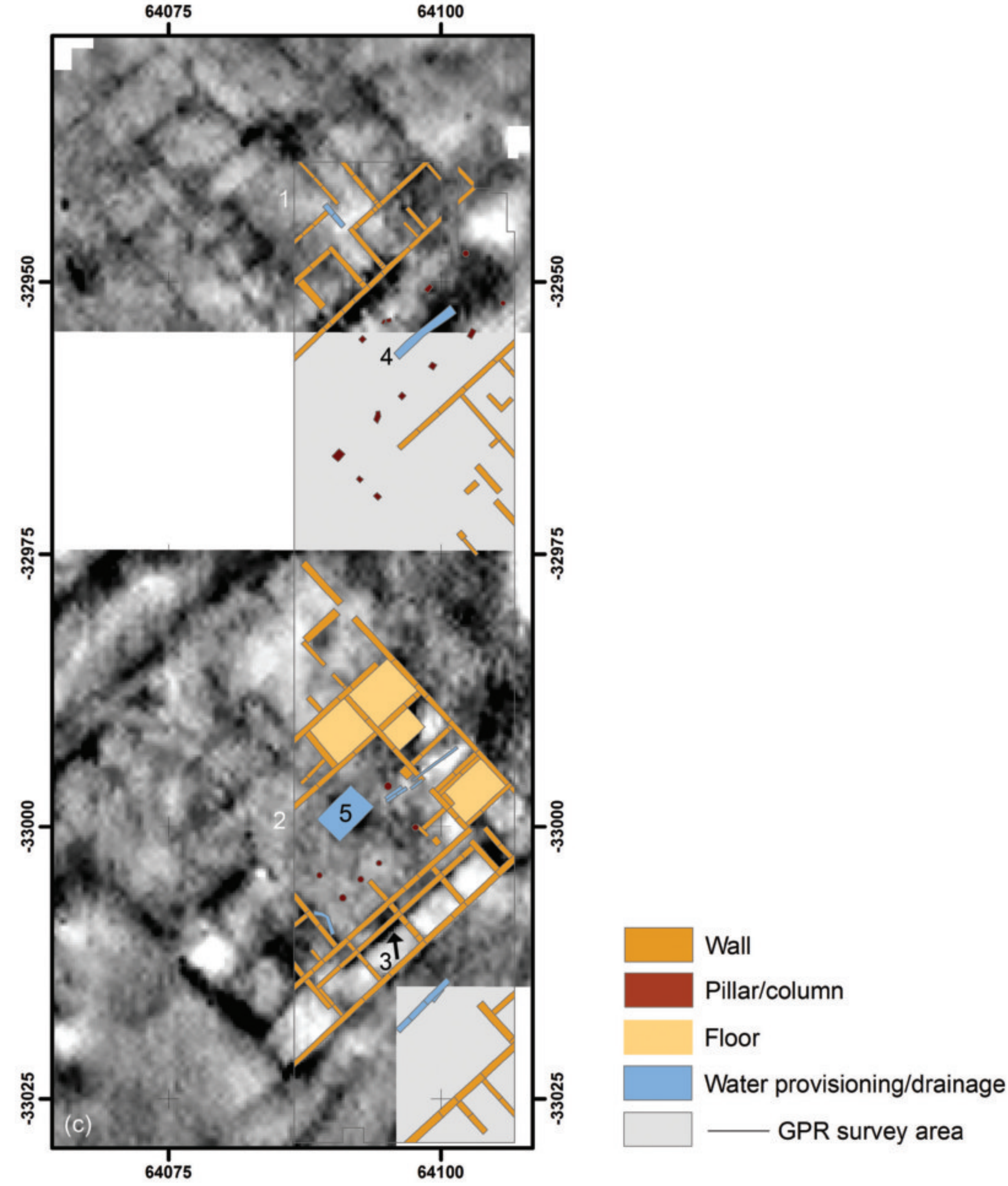

Fig. 94 Archaeological interpretation of the GPR data overlying the earth resistance data of a large *domus* in *insula* XXIV (elaboration L. Verdonck).

In most cases where distinct house plans could be detected in *Ammaia* we are confronted with smaller units and more irregular plans. Often small courtyards are foci for a series of rooms around them or along some of their sides, while many *insula* edges are occupied by rows of *tabernae* opening onto the street. These smaller units seem to represent areas of lower- and middle-class housing, be it that some of them approach the aspect of more distinguished *domus*.

The refined interpretation of the structures detected via GPR survey in Block X (section II.5.c) has suggested an original articulation of the total surface of circa 2700m^2 in 10 housing units, which, with the exception of unit 1 and possibly unit 2, would all have been open on the two *decumani* delimiting the block on the northern and southern long sides. If the proposed interpretation is correct, we can distinguish 10 rectangular houses of different sizes, measuring between circa 200 and 400m^2. The spatial distribution of rooms inside the houses of this block seems not to be exactly repeated in the rest of the town, so that we cannot assume the existence of a fixed rule or module to regulate the domestic urban pattern in most blocks. Still, the regularity with which the *insula* is subdivided laterally in two series of probably five houses, demonstrates a well-organized town planning. The plans of these houses also do not exactly replicate known examples of excavated town houses with the typical *atrium* or *peristylium* configuration, as we know well from Italian and

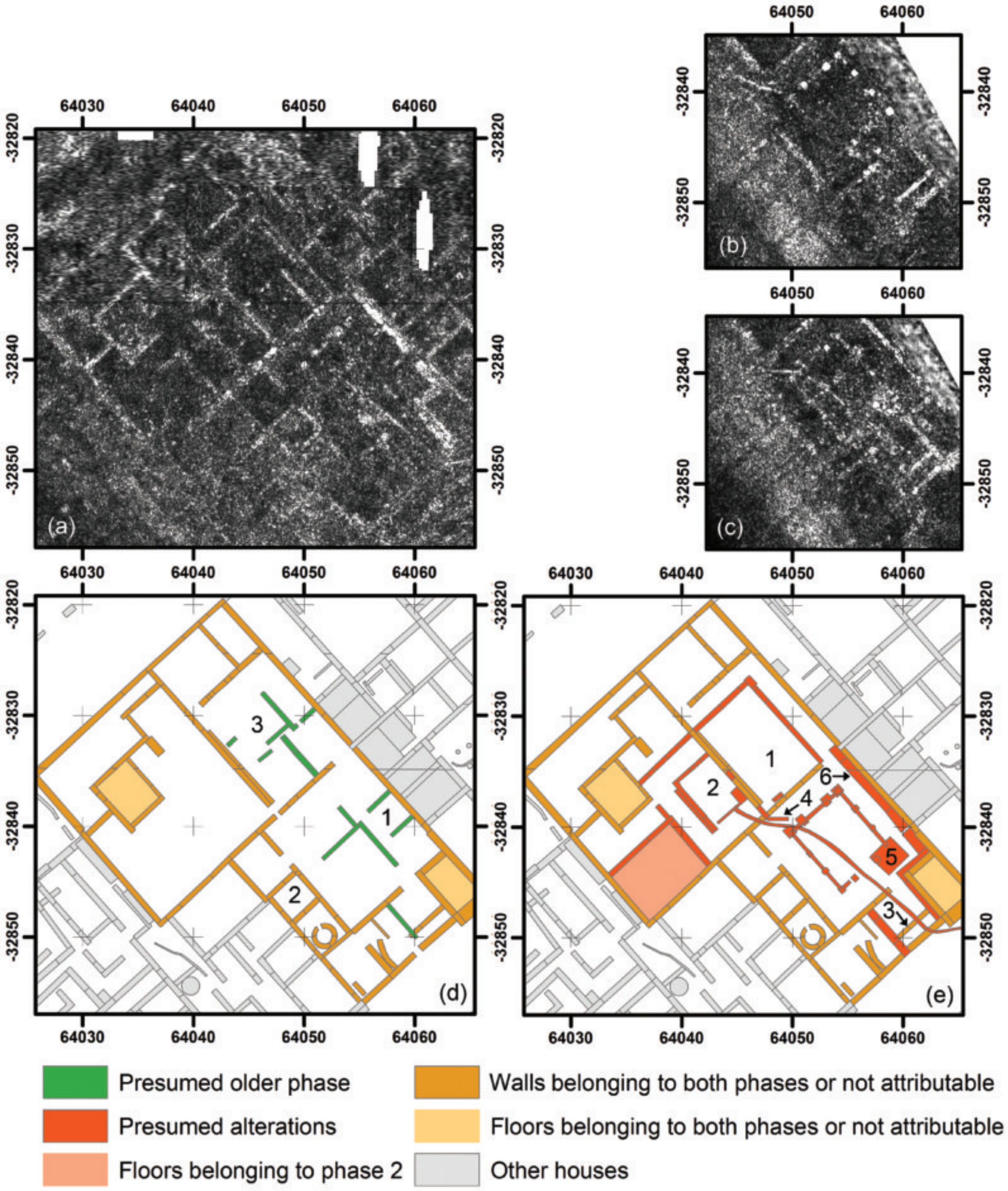
(a)
(b)
(c)
(d)
(e)
64030
64040
64050
64060
-32820
-32830
-32840
-32850
1
2
3
4
5
6
🟩 Presumed older phase
🟥 Presumed alterations
🟧 Floors belonging to phase 2
🟧 Walls belonging to both phases or not attributable
🟨 Floors belonging to both phases or not attributable
⬜ Other houses

Fig. 95 (a-c) Images derived from the GPR survey in *insula* X and (d-e) archaeological interpretation of the data, showing structures presumably belonging to a first and a second building phase (elaboration L. Verdonck).

other Mediterranean contexts. Nonetheless, in some houses we can easily define the basic scheme of organisation, with a central or slightly decentralized axis joining the entrance corridor (*fauces*), flanked by rooms or *tabernae* opening onto the street, to a central courtyard (*atrium* or small *peristylium?*) or centrally placed room, onto which several rooms open. Of these courtyard rooms we sometimes distinguish a larger room but its function is not clear (*tablinum* or an *oecus*?). In certain blocks where detailed information is available we see that part of the space at the back is possibly reserved as an open area (*hortus?*)[3] but this interpretation is not evident without excavation.

In general these houses show great individuality, within their regularly conceived housing blocks. Some are a bit larger and more regular, and seemingly reflect, also by the presence of a larger courtyard with columns, the will to emulate the better *domus* in town. A greater internal social mobility, and change in the financial possibilities and fate of the owners through time, might explain why these houses seem to be much more the subject of structural alterations and sometimes serious reorganization. This phenomenon has been successfully picked up by the high resolution GPR prospection in several housing blocks (Verdonck 2012b: 180-183). In particular in *insula* X, it is suggested that two original house units, measuring respectively some 410 and 270m² and situated on both sides of the "spine' of this housing block, were at some moment joined into one larger house (Fig. 95). This large house has then not only procured itself with a large courtyard with columns, but also a very large *triclinium* or *oecus* flanked by a water basin with possible fountain. In this way the house, now a good 680m², was raised in size and status to the level of the larger *domus* elsewhere in town.

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[3] Such as for the *domus* identified in Blocks XI and XV.

The wide diversity of plans of the more modest houses is very difficult to appreciate with prospection techniques only. The modest size and more irregular plans prevent often from properly identifying the full house units. This is not helped by the many transformations which can be observed in some housing blocks, such as in Block XXXV. Interesting in this respect is a series of small and irregularly constructed houses or buildings along the road leaving the town at a presumed small gate or *posterula* in the far southern corner of the circuit wall (Blocks XXXIV and XXXIX). These simple and somewhat irregularly constructed buildings do not display the regular features of one-room *tabernae*, but give the impression to be poorer housing added to the town plan in a later stage of its development.

Finally, certain elements picked up during the geophysical surveys point to interesting architectural diversity or characteristics, probably in part a reflection of different scales of social levels among the inhabitants. Such is the presence of apsidal rooms as part of private bathing facilities or special rooms for receiving guests[4], or the bipolar anomalies in some occasions hypothetically related to the presence of heating systems[5]. When focusing on these factors, we must admit that the distribution in town is uneven, and that we cannot classify some sectors as “upper class” reserved or only inhabited by financially stronger *Amaiaenses*.

Parallels in the Iberian context

What is now documented in the discoveries at *Ammaia*, finds some parallels in other Lusitanian and Hispanic towns. Again the most interesting comparisons are found in the nearby provincial capital *Augusta Emerita*, where the extension and the accuracy of the data from excavations allow identifying the initial phases of Roman settlement as well as later developments and transformations. Here, most interestingly, the building blocks are often divided in 6 units, with identical plan and dimensions, displayed in two rows on each side of the *insula* (Alba Calzado 2004b: 238). In Mérida we find also good comparisons for the presence of apsidal rooms. Particularly instructive is a vast *domus* brought to light at the beginning of the twentieth century, when the room with the apsis was interpreted as a Christian basilica (Durán Cabello 1991: 360-361). The fact that many materials are reused confirms the late imperial chronology for this phase. Oddly, the final phases of this complex foresee the encroachment on the circulation area around the theatre (Durán Cabello 1991: 366-369). Also useful is that in this town some houses of the lower classes were excavated: they represent simple buildings of quadrangular shape and small dimensions (40m²) with only 5 rooms simply disposed 2 by 2 on both sides of a central corridor (Alba Calzado 2004a: 82, fig. 40).

The three larger *domus* in *Ammaia* presented here with some detail find easy comparison also in several other Roman towns of the Iberian peninsula, such as excavated Roman houses in *Italica,* e.g. Casa de los Pajaros (Caballos, Marín Fatuarte and Rodríguez Hidalgo 1999), Casa 1 and Casa de los Morillos in *Iuliobriga* (Cepeda Ocampo, Iglesias Gil and Ruiz Gutiérrez 2008), the Casa estramuros 1 in *Conimbriga* (Alarcão and Étienne 1977), the *domus* of Albergue Distrital in *Braga* (Uribe Agudo 2008) and the Maison de l’ouest in *Baelo Claudia* (Teichner 2007 and Meyer 1999). They are *peristylium* houses displaying a good sense of axial organisation, with a central peristyle surrounded by a colonnade and by more or less symmetrically placed rooms, dominated by the most important reception and dining room (*triclinium*) in the axis of the house. In all these examples, as in *Ammaia*, the peristyle worked as an organizer and distributor of space with a decorative meaning and as source of light and air into the housing. The architecture follows the main trends of prevailing house types in the wider Mediterranean area, but the private nature of housing can establish that the canonical models are not met fully. Moreover, the economic power of the owner and his personal tastes, as well as the space available for construction of the dwelling unit, are all factors that greatly influence the morphology of the particular private architecture. These are “Roman houses” but “Roman houses” adapted to local conditions (Uribe Agudo 2008: 616).

The examples from *Celsa* (today Velilla de Ebro[6]), in the Ebro valley, are interesting for the remarks made here about the traditional – but unmotivated – reconstructions of the houses with a second floor. In fact, a revision of the excavation data allowed Beltrán Lloris (1985: 44-48) to propose that only the latest phase of “Casa A” implied the construction of a second floor around the atrium roof, while in the “House of the dolphins” the existence of a second floor can

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[4] Such as in: Block II, magnetic anomaly no. 7; Block XIX, magnetic anomaly no. 77; Block XXV, magnetic anomaly no. 106; Block XXXV, magnetic anomaly no. 145.

[5] See: Block XIX, magnetic anomaly no. 77; Block XV, GPR no. 43.

[6] The town was founded by Lepidus on a pre-existing indigenous village, and during the years of the Julio-Claudian dynasty it was already eclipsed by the new capital of the district *Caesaraugusta* (Beltrán Loris 1985: 32-43).

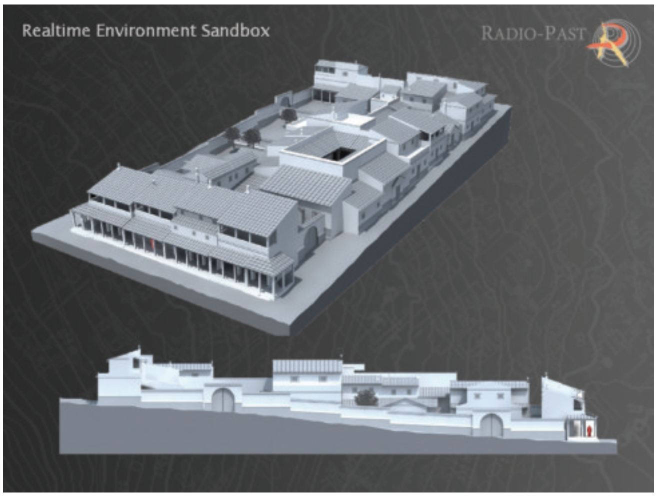

Fig. 96 Impression of a housing block in *Ammaia* with disposition of the houses according to the ancient topography (elaboration M. Klein).

be hypothesized (Beltrán Loris 1985: 63)[7]. In *Celsa*, there is evidence also for other types of houses than the *domus*: the *insula* II is articulated in several complexes, some of which include *tabernae* and a baking oven (Beltrán Loris 1985: 66 ss.). Indeed, here houses are classified in two main types: those belonging to people that "do not have to receive *clientes* because they are *clientes* themselves", ranging between 400 and 100m^2, and the highest class *domus*, of which only one is known (the above mentioned "House of the dolphins"), with 3000m^2 (Beltrán Loris 1985: 114-117). The building techniques are of course mainly related to local traditions and geomorphological/geological factors, but it can be interesting to notice that in *Celsa* mainly local limestone is used to build a socket of masonry, on which the walls are erected using adobe, later coated with mortar (Beltrán Loris 1985: 109-111). The mostly survey data from *Ammaia* do not allow here to evaluate the appearance and frequency of this building style.

In other cases, like in Ampurias, we can follow the progressive "upgrading" of the local elites testified by the expansion in stages of the existing *domus* (Santos Retolaza 1991: 33-34) as we suggested for one well observed housing block in *Ammaia*. The houses in Mediterranean bordered Ampurias are clearly more inspired by the central-Italic re-elaboration of the Hellenistic models than we see in our central-Lusitanian context. It may be interesting to notice that in *Emporiae* these richer *domus* are located in the westernmost areas of the town, while the political, administrative and commercial centre of the town seems to be more attractive for the middle classes, which, here too, occupy houses of smaller dimensions (Santos Retolaza 1991: 33-34). Comparable is the situation in *Carthago Nova* where smaller houses, built in Augustan times, seem much derived from the typical Italic *atrium*-type but with simpler disposition of a relatively limited number of rooms (5 to 7) around the *atrium* and with dimensions (less than 400m²) comparable to the ones we were able to study in *Ammaia*'s Block X (Ruiz Valderas 2001: 65, fig. 3). As we suggest for *Ammaia* also in *Carthago Nova* these middle-class houses seem to have a simpler *atrium*, often reduced to a kind of central room for connections to other spaces or even a reduce to a *vestibulum* with direct access to the street and without the classic open roof and *impluvium*.

Conclusion

The external parallels for housing in *Ammaia* are certainly useful, but it is also clear that each Roman town has its specifics and that *Ammaia* probably does not fully fit in the general picture we have at present of small to mid-sized towns in the Iberian Peninsula. Even if more excavations, field tests and material studies are surely needed to fully write the occupation history of this town, we dare to suggest that here, because of certain social and economic conditioning factors, the "conflict" between the leveling system of the regular orthogonal layout and the expansion of the urban bourgeoisie remained quite limited. The distance in size and quality between the largest *domus* and most smaller houses seems not very great and the parts of town which allowed regular house building were also very fully and systematically taken in. At this stage of research, there is no evidence of an "overflow" outside of the city walls by the elites in search of available space for the richest *domus*[8], but we do remark a modest internal expansion of some mansions to rise to a higher level of housing status. Assembling all the data we collected with different types of survey and integrating them with the limited evidence from the excavations, we can observe in several sectors of the urban center of *Ammaia* different levels of dynamism in transformations, but we cannot fully establish if these changes are due to remodeling activities inside the buildings rather than substantial urban transformation[9].

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[7] This discussion is not without importance for an estimation of population numbers. In *Celsa*, during the apogee of town occupation, Beltrán Loris (1985: 108) proposes an estimate of some 3000 citizens, a number that could be quite comparable to what existed in *Ammaia*.

[8] Such is the case presented by Gros (2001: 399) in Timgad, where the urban grid of 20 by 20m prevents the wealthiest citizens to build their mansions inside the town and pushes them to search for available space in the *suburbium*.

[9] This remark has been made, e.g., for *Augusta Firma Astigi* (Ecija, near Seville): Rodríguez Temiño 1991: 353.

III.2 THE SUBURBAN AREA AND THE AQUEDUCTS

F. Vermeulen, C. Corsi, C. Meyer

The ancient city was not an island, but just a node in a flexible and constantly changing grid. Its impact on the surrounding landscape was often impressive and the tight nexus of city and countryside was essentially a relationship of interdependency. Archaeological research of recent decades has now developed a set of tools which helps to demonstrate more vividly this urban impact on the countryside (Corsi and Vermeulen 2010). Earlier in this book we have demonstrated that especially a more pronounced and integrated use of a whole set of non-destructive survey techniques on (now abandoned) towns and their territories allows fast advancement of current knowledge on the town-country nexus in Roman times. Our emphasis, however, was on the urban center itself and its immediate *suburbium*. For the wider territory depending on the urban core of *Ammaia* this approach is still a work in progress. Much needs to be learned about the wider economic exploitation of this hinterland of a medium-sized Roman town in *Lusitania* and there is definitely a real need to start a program of intensive and systematic "rural surveys" which could contribute fundamentally to acquiring knowledge on how the new Roman town was able to flourish and survive for several centuries. As a result of our research choices we will only briefly summarize here some of the main known elements of importance concerning this wider territory, linking up with work done in this area in the past. Thereafter, we will try to synthesize the essential new acquisitions concerning the immediate extra-mural areas of *Ammaia*, as they have been revealed since more systematic surveys started here in 2001.

The economic hinterland of *Ammaia*

The exact extent of the ancient territory of Roman *Ammaia* remains unknown. It roughly comprised the northeastern Alentejo region probably extending to the north up to the River Tejo and to the east deep into modern Spanish Extremadura. Its extension was hypothesized by Vasco Mantas (Mantas 2000 and here chapters I.1 and I.3) on the basis of epigraphic evidence and the identification of certain natural elements, such as rivers, which could have marked well distinguishable limits. This assumed territory of almost 4000km^2, with *Ammaia* as centrally located focus and capital, is not rich in resources allowing for rural societies to sustain very dense populations. As detailed above, in chapters I.4 and II.1, the wide hinterland of *Ammaia* was most often characterized by shallow soils, generally not very suited for intensive agricultural purposes and high grain yields, but evidently, in Antiquity like today, ideal as pastureland for cattle and pigs, and possibly for cork and olive production. The hilly landscape in which *Ammaia* takes up a very central position, the Serra de São Mamede, however combines a series of important assets for such sedentary populations, such as abundant water (rivers, brooks and springs), exploitable stone (mainly quartzites, schists and granites), wood and a wide variety of mineral riches (e.g. gold, lead, silver, hematite, rock crystal).

Due to the lack of good excavation and systematic survey evidence it is still unclear how exactly these landscapes were being exploited and populated in the period immediately preceding the establishment of the town of *Ammaia*. While for the central and southern Alentejo several real Iron Age towns are known (e.g. *Conistorgis*, *Mirobriga*, *Ebora*: Alarcão 1988), only smaller settlements have been identified in the territory of *Ammaia*. Sites such as Vaiamonte and Vidais 2, which were occupied at least from the fourth to the first century BC ((Correia 1999-2000; Boaventura and Langley 2006; Oliveira, Pereira and Parreira 2007; Pereira 2009; Mataloto 2010) show groupings of up to 15/20 families with a subsistence based on a mixed agro-pastoral economy and important exploitation of minerals. While the southern part of the territory of *Ammaia* shows a denser occupation of the rural landscape with small- to medium-sized sites (Mataloto 2010), the more mountainous area of the Serra de São Mamede, around the later urban centre, seems quite poor in late Iron Age settlements. A real population centre, pre-dating the definitive integration of the area south of the River Tagus under Roman dominion, in a time roughly between the conclusion of the Sertorian wars in 72 BC (Alarcão 1988; Collins 1994) and the Augustan organisation of the region (Mantas 2000), has not been found yet. That such a centre should be sought on the dominant hillcrest where today lies the medieval village of Marvaõ, is thus far only an interesting hypothesis. Maybe, a more likely scenario is that families and individuals from the rural settlements dispersed over the whole later Roman territory of *Ammaia* took part in the gradual and possibly even temporarily imposed filling up of the new town centre. This must have succeeded a period at the very end of the Republic (second half of the first century BC) of increased instability in the general area south of the River Tagus, when more and more Roman immigrants arrived (Alarcão 1988). In several areas surrounding the territory of *Ammaia* this is archaeologically illustrated by networks of tower enclosures and fortified rural sites, erected around the middle of the first century BC in strategic positions in the landscape and abandoned again in Augustan times (Calderón Fraile *et al*. 2000; Mataloto 2010). The abandonment of these sites seems directly related to the foundation of a Roman political and territorial control system of the area with proper Roman towns. Like other towns in the province of *Lusitania*, *Ammaia* undoubtedly functioned as an urban and political-administrative centre from where the surrounding lands of the northeastern Alentejo and western Extremadura regions could be governed efficiently (Taelman 2012).

During the Roman Imperial period much of the exploitation of the landscape within *Ammaia*'s territory must have continued along the same lines as in the preceding Iron Age, even if a distinct intensification and densification of settlements is very obvious. In the southern districts, where the soils allow for more intensive grain cultivation, relatively high densities of rural exploitation sites and especially some large and richly furnished villas (e.g. Torre de Palma, Tapada da Pedreira, Pombais 1, Mosteiros) indicate that at least that part of the region was agriculturally well-exploited between the first and the early fourth century (Gorges 1979; Maloney and Hale 1996; Alarcão 1998; Almeida 2000; Carneiro 2004; Monteiro 2011). After the fourth century only some large *villae* maintained their status for a long while, regardless of signs of a reduced wealth and of the gradual collapse of the larger population centres, such as can be seen in the urban core of the system at *Ammaia* (Vermeulen and Taelman 2010; Corsi, Johnson and Vermeulen 2012). In the immediate neighbourhood of this urban core, meaning the inner *suburbium* within a range of some 10km from the town centre, the number of known Roman rural establishments is relatively poor (Oliveira 2005; Taelman 2012). Only in the area immediately to the north a somewhat denser dispersion of Roman farms and farmsteads was noticed, but again more systematic surveys are needed to confirm this pattern. Anyhow, the more mountainous landscape of the town's immediate surroundings does not suggest the development in Roman times of large grain based estates, but a more humble type of rural sites, based on mixed farming possibly with important olive cultivation, pastoral activities (where the production of pork might have had an important share) and woodland exploitation. Furthermore, as has been stressed above (see I.4) the mineral richness of that area and of the northern and eastern sectors towards the rivers Tagus and Guadiana and nearby smaller rivers in the area such as the Ribeira de Nisa and the Sever, undoubtedly greatly appealed to the Roman settlers. The proven Roman exploitation of gold on the left bank of the Tagus River and of lead, iron and copper (Coelho 1988; Oliveira, Pereira and Parreira 2007; Deprez *et al*. 2009; Taelman 2012) indicates, together with the clear evidence for the quarrying of granite, limestone and rock crystal nearby the town site, that the populations living here in the first centuries of our era, fully exploited the potential of the land. Particularly well documented by the new research presented here is the large scale and systematic exploitation of the Pitaranha quarry, where most of the granite for architecture in the town and its immediate hinterland was exploited.

Roads and bridges

This pivotal role of *Ammaia* as economic center for a whole territory, connecting the town at the same time to the wider province of *Lusitania* and beyond, is made possible by a well developed road network. The present-day reconstruction of the general trajectory of the main Roman roads is determined by the location of known Roman urban and rural centers, preserved stretches of roads, bridges and milestones. In addition, the interpretation of certain vertical aerial photographs and the study of the local topography can sometimes provide important clues about the precise trace of the roads. It is not the place here to discuss at length the current evidence about the main road network in this part of *Lusitania*. This has been done elsewhere on a wider scale (e.g. Saa 1956; Alarcão 1988; Mantas 2012) and although a few detailed studies have recently explored the Roman road network closer to *Ammaia* (Carvalho 2002; Corsi and Vermeulen 2008; Carneiro 2009; Almeida *et al*. 2011) very few archaeologically tangible remains of the roads have been discovered to date. It can, therefore, suffice to synthesize briefly the main picture of this network (see also Taelman 2012).

According to the *Itinerarium Antonini*, the capital *Emerita Augusta* was connected with *Olisipo* (Lisbon), its principal oceanic harbour, through three different main roads (Alarcão 1988). Two of these run through the southern part of *Ammaia*'s territory, following predominantly an East-West orientation. Along their trajectories in this territory a dense rural occupation with important Roman *villae* and some subregional centers or *vici,* such as *Abelterium* (Alter do Chão) and the *vicus Camalocensis* (Crato?) have been identified (Carneiro 2009). A dense network of secondary or regional roads linked *Ammaia* with its hinterland and with the mentioned major roads, and thus with the main Roman towns in the southern and central parts of *Lusitania*. These secondary roads and routes are essential in structuring the rural landscape and for the town's economic development. As *Ammaia*

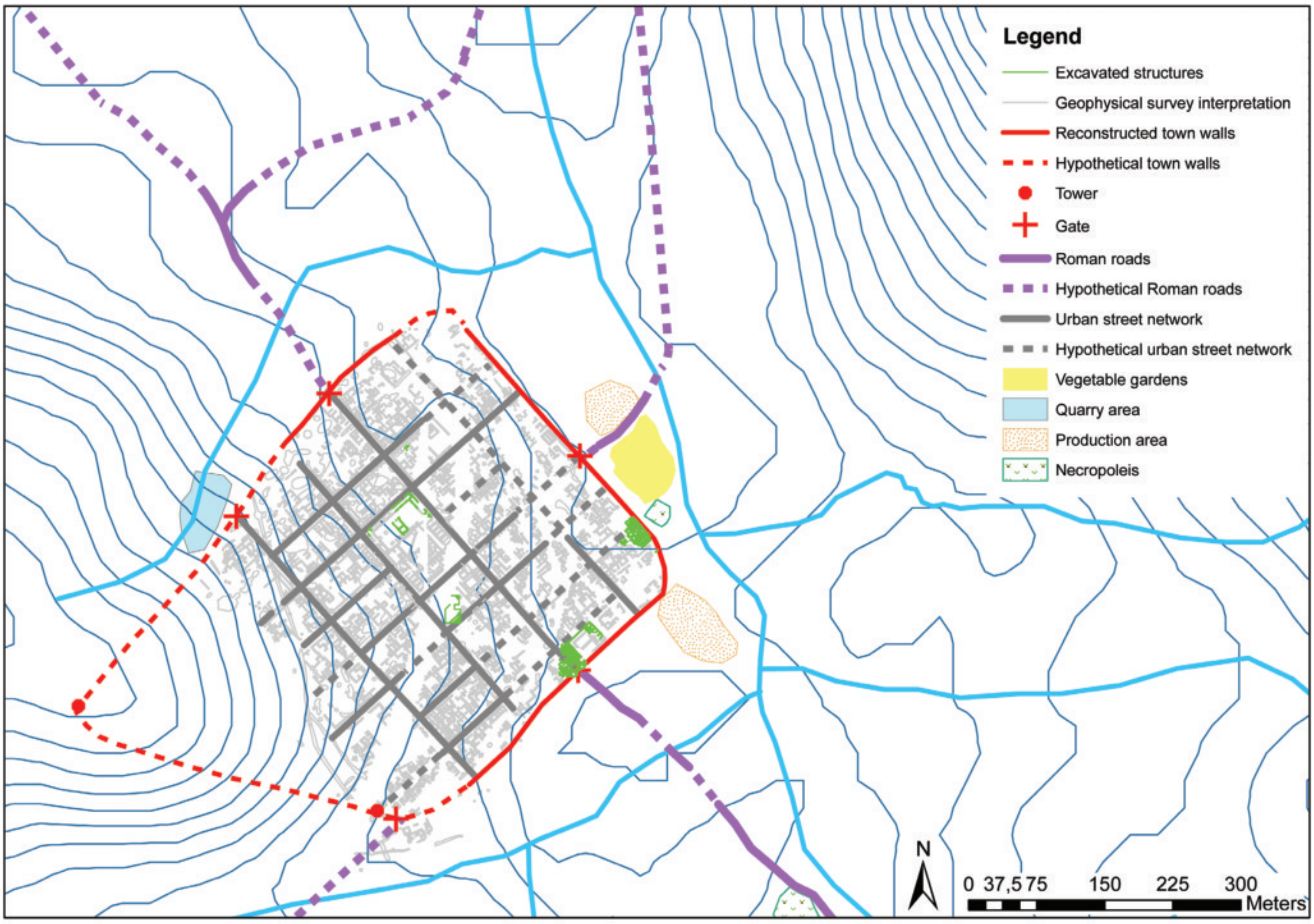


Fig. 97 *Ammaia* and its *suburbium*, with hypothetical definition of the wall circuit and indication of the excavated areas, necropoleis, possible industrial and waste disposal areas and suburban road-network (elaboration C. Corsi).

lies in a hilly landscape, these roads often need to cross rivers and brooks and accordingly small to larger bridges are needed. Based on all evidence, including the new data from our recent geomagnetic surveys in the *suburbium* of *Ammaia* (section II.5.f), several attested roads connect the town with its hinterland and with the rest of *Lusitania* (Fig. 97).

The most important road for *Ammaia* was evidently the one to the provincial capital *Emerita Augusta*. It leaves the town at its monumental south gate, where its scanty remains were excavated (Pereira 2009: 62-77), to leave from here in a straight line in a southeastern direction. Some 150m from the gate it crosses the small Ribeira do Porto da Espada at a point where probably no real bridge was needed but traffic could wade through. Some 200m further we picked up its trace in the magnetometer surveys and could follow it at least for 80m where a small junction occurs. The main branch crossed the River Sever here, while a local track seems to follow the right bank of that river, possibly to connect with local farms. That main branch follows the Sever valley, passing along modern villages like Porto da Espada, São Julião and La Codosera (Spain). Near Alburquerque, the road turns southwards to run along the River Xévora and finally at Butua connects with the main road from the West leading into *Emerita Augusta* (Carvalho 2002; Corsi and Vermeulen 2008; Carneiro 2009).

A second road exits the town at the south gate, but switches immediately in a southwestern direction. Maybe also a road for smaller traffic, leaving from a secondary gate whose location at the southern corner of the wall circuit is proposed by the intra-mural geomagnetic prospection (II.5.b), joins up with this road. At about 150m west of *Ammaia*, the road crosses the Ribeira do Porto da Espada at the location of the ponte de Madalena where the emplacement of an ancient Roman bridge is preserved (Carvalho 2002). After crossing the river, the road continues in the direction of Carris and Alvarrões, partly follows the valley of the Ribeira da Nisa and passes near Fortios before reaching the main road to the south between Crato and Assumar. This road formed a direct connection with the Roman town of *Ebora* and the important marble quarries of the Estremoz area (Carneiro 2009; Taelman 2012).

A third road leaves the town from the presumed gate located near the midpoint of the NE side of the walled enclosure. Its trace is picked up by the extra-mural magnetic survey and it leaves this gate first in a northeastern and then, near the River Sever, in a northern direction. At Ponte Velha, the road divides into a northern and an eastern trajectory. The northern trajectory passes through a zone of intensive rural exploitation with many Roman *villae* and smaller farms. Further to the north, the road might connect with the road going to the River Tagus in the direction of *Aegitania* (Idanha-a-Velha) (Carneiro 2009; Mantas 2012). The eastern trajectory probably continues to the town of *Valentia* (Valencia da Alcântara?) and *Norba Caesarina* (Caceres), the neighbouring civitas capital, following more or less the same course as the modern road from Marvão (Carvalho 2002; Corsi and Vermeulen 2008).

Finally, a fourth road leaves town from the presumed gate in its northwestern walled side, with the same orientation (45° NW) as the intramural *cardo maximus*. It is picked up by the magnetic prospections at some 300m distance from the wall (where also a local split of the road towards the River Sever occurs) and according to the analysis of vertical aerial photographs it continues quite regularly with this same northwestern orientation for at least a couple of kilometers. It seems to connect *Ammaia* with *Aritium Vetus* (Alvega?) where an important crossing of the River Tagus River is proposed, passing on its way Castelo de Vide and an area with several Roman *villae* and farms. It is also seems to connect *Ammaia* to the main central Lusitanian road system and eventually to *Olisipo* (Lisbon) in the west (Carvalho 2002; Corsi and Vermeulen 2008).

The extra-mural activities and structures

A whole series of extra-mural activities can be imagined around a quite typical Roman provincial town like *Ammaia*. Some of these have now also been archaeologically attested since our surveys started in 2001, while others can be suggested or supposed, partly by older finds. This *suburbium* must not be perceived as a concentric system of equal distance to the forum and walls, but with a radial system linked to the roads leaving the town and regarding the cost and ease of travel and movement from it. This “marginal zone of a city” has its own history of evolution and devolution, with alternating phases of vitality: productive, functional and settlement (Antico Gallina 2000: 106). A founded or regularly conceived city like *Ammaia* had its clear demarcation by walls, but also by a peripheral communal area that was still considered part of the *pomerium* and thus in a way public. Only with time this strip could be privatized partially for all kind of functions connected with the life of the city and its inhabitants. This public belt was normally occupied by public *ustrinae*, common pits and funerary areas for the poor, by *horti* reserved for specialized cultures valuable for the city’s economy, for artisanal activities and all kind of peripheral housing, for hosting people and stables. Evolution is very important here and is often more dynamic than in a fixed and fully built intra-mural area. Especially in Late Antiquity shrinkage of city life implies sometimes the use of the direct suburbs first as quarry and recuperation zone, and after that as sector for more disorganized burial or waste disposal (Bedon 1998: 17). Let us now have a look at some indications we have for *Ammaia* and see if this typical pattern also occurs here.

Even in a society where regional and even long distance trade had much increased, this nearby *suburbium* retains its crucial role for provisioning (Lafon 2001). This is especially the case for food products: fresh products like fruit, vegetables, flowers that come mainly from the garden belt around many towns and in particular from the *horti rustici* (Plin., *Epist*. 2, 17), but often also wine and oil production. In *Ammaia* certain structures picked up by the magnetic survey between the NE side of the town wall and the River Sever point to such functions. Enclosures around quite large open spaces found here might indeed be interpreted as serving for such *horti*, while also less specific structures on the SE side of the extra-mural belt come into view for this function of market gardening areas with their own paths and demarcations or enclosures.

Often also specific areas of industrial activity are located immediately outside the walls, evidently in relation with the transport facilities, the presence of primary goods (clay, wood, bedrock, gravel…), the space necessary for technical facilities, the presence or availability of water or of evacuation channels or ditches, such as the ditch surrounding the city and drainage function of the nearby River Sever. In *Ammaia* these areas seem to be located on practically all sides of the town. On the northwestern side, near the steeper part of the slope of Malhadais hill, where earlier research had presumed the presence of a Roman theatre based on a semi-circular feature visible on aerial photography (Mantas 2000; Vermeulen *et al.* 2005), lies an ancient quarry related to town building activity. This sandstone quarry was identified in 2011 by way of geological and geomorphological observations combined with a geomagnetic survey (Taelman 2012: 184). It consists of a clear exploitation front and remains of spoil heaps connected with the extracting activities. The Roman quarry provided well-cemented brownish sandstone used as building materials in the intra-mural parts of the city.

Immediately north of this quarry area, along the outgoing NW oriented road to *Olisipo*, the same magnetic prospections discerned an area with highly magnetized material and many traces that could be related to ancient metal works. Further work is needed here to confirm the character of these possible artisanal or industrial activities. This applies also to a narrow area between the walled town and the River Sever. Here, however, the magnetic survey also revealed building structures, on both sides the main road leaving the town as a prolongation of the *decumanus maximus*. The metal detector survey revealed here the presence of many metal artefacts and some slags, indicating a function at some moment in time connected with metal works and small suburban industry, a suggestion also corroborated by the general artefact collections in this arable area. This agrees well the discovery during the recent excavations (2002-2006) of the museum parking area (see chapter I.2), of some structures related to a possible metal workshop (Pereira 2009: 117).

Another typical activity to be expected in the extra-mural zones of a classical town is of a funerary nature (Castoldi 2000). The trend to line up the Roman cemeteries along roads demonstrates the will to spread out the regular city-planning practice to the territory. Areas of *necropoleis* were probably considered from the start as undividable terrain, not to be used for agricultural purposes and lying close to the roads leading out of the urban center. In *Ammaia* we have now indications for at least three cemetery zones bordering the walled city and its outgoing roads. Older and not well documented excavations in the area just north of the town, alongside the first part of the northwestern road have revealed scattered remains of an important Roman necropolis near the modern church and surrounding houses of São Salvador da Aramenha (Coelho 1988; Pereira 2009). Also the epigraphy preserved on dislocated tombstones (see chapter I.3), now kept in the local site museum, as well as some older collections of intact burial goods, disclose evidence of important burial activity around the town. The only well documented excavated proof of this is given by the remains of a monumental tomb made out of large granite blocks found during the recent excavations directly outside the eastern angle of the circuit wall, under what is now the museum parking (Pereira 2009: 104; Fig. 98). A comparable monument was possibly located just outside the southern angle of the town circuit, if the proposal from the magnetic surveys in that area can be confirmed (see II.5.b, magnetic anomaly no. 181). Even more convincing, however, are the most recent results of the geophysical surveys in the southern extra-mural part of the town, where we observed a series of mostly rectangular features along the road to *Emerita Augusta*, suggesting the presence of a large necropolis in this area. This presence is further corroborated by the analysis of the newest vertical aerial photographs for that area. Here, as well as possibly along the outgoing northwestern road, the most prestigious tombs of the elite families of *Ammaia* would have greeted the visitors to the urban center. They were no doubt surrounded by many simpler plots and burials connected with the broader layers of local society.

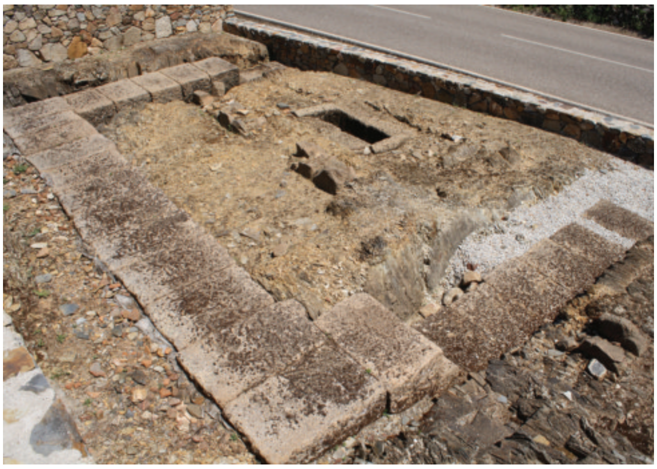


Fig. 98 View from the south on the partially excavated early Imperial funerary monument outside the eastern angle of the wall circuit.

The funerary landscape of *Ammaia*, can be therefore reconstructed like the ones of other Lusitanian (Caetano 2002; Fabião 2008) and Spanish (Jiménez Salvador 2002) towns.

Even if the data from the magnetic survey do not allow stringent comparison with better documented monuments from neighbouring towns, the examples of monumental *arae* from *Augusta Emerita* are surely represented here (Nogales Basarrate and Márquez Pérez 2002: 124-126), as proven by the fragmentary *pulvinus* preserved in the *Ammaia* Museum.

Water provisioning

Finally, we must stress the importance of the extra-mural areas for the provisioning of water to the ancient city population, and its predominant role for installations for irrigation, drainage, the use of cisterns, the distribution of water to cattle and aqueducts to also serve the fields bordering the town (Lafon 2001). The presence of good drinkable and sufficient water outside the walls remains often a crucial element in the organization of the suburban area, as well for city provisioning as for rural hydrology (Campanelli 2000: 86). The location of the urban settlement *Ammaia* was surely partly conditioned and determined by the numerous natural springs in the area of the Serra de São Mamede. The perennial rivers Sever and Ribeira dos Alvarrões were key water sources for the town inhabitants, where water could be collected easily (Deprez 2009). Thanks to the geoarchaeological surveys conducted in the area since 2001 (see I.2) we now know that the Romans constructed also two aqueducts to transport enough large quantities of good water into the urban area for supplying high water consuming structures, such as bathhouses, fountains and latrines. As this new evidence has been published quite extensively (see

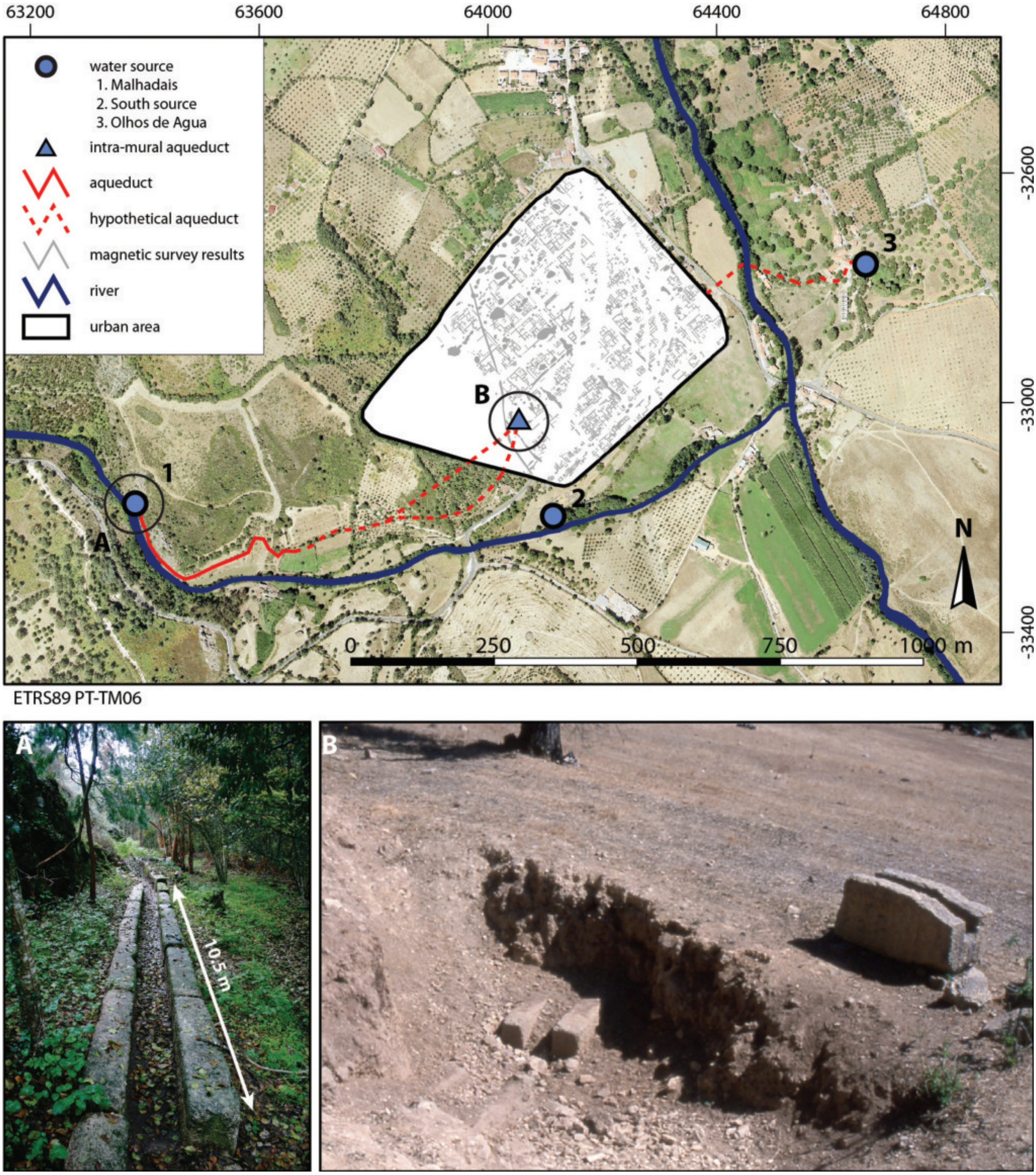


Fig. 99 Important water sources near *Ammaia* and reconstructed trajectories of the two Roman aqueducts. (A) Western aqueduct consisting of U-shaped granite ashlars near the Malhadais capture, (B) Specus of U-shaped granite ashlars found inside the urban site (elaboration and photos D. Taelman and M. De Dapper).

especially: Vermeulen *et al.* 2005; Vermeulen and Taelman 2010; Corsi and Vermeulen 2012; Taelman 2012) we will only summarize the results here, providing some additional data regarding the connection with the water distribution inside the town.

A primary source to bring high quantities of water to the urban settlement is part of the aquifer system of the Escusa dolomitic limestones that stretches out between Castelo de Vide and the Spanish border, following the flanks of the Serra de São Mamede. At some 300m east of the *Ammaia* walls, at Olhos de Agua, on the opposite side of the River Sever remnants of Roman water capture structures were discovered (Fig. 99, 3). Remains of columns found in the same area could even indicate the presence of a *nymphaeum* in this location. The spring lies about 8m higher than the eastern part of the intra-mural zone and could, therefore, supply only the lower parts of the town. The Roman conduit system was probably fully dismantled during the construction of a nineteenth century mill which was built in that area.

Excellent archaeological evidence was, however, discovered in the area south of the Malhadais hill, in a zone of almost 1km west of the town. Remains of a river capture and a typical Roman *specus* construction, made of U-shaped granite ashlars (*c.* 1.5m in length), were found on the southern slopes of this hill, just above the winterbed of the Ribeira dos Alvarrões (Fig. 99, 1). The aqueduct neatly follows the topography with a light gradient and part of this construction reveals itself as a rock-cut conduit that could be traced over a length of approximately 700m. Its first part inside the walled area was not located due to the intensive vegetation on the steep sloping western part of the town. Possibly the aqueduct must have been connected with a *castellum aquae* needed for filtering and pressure control.

From here distribution over practically the whole intra-mural area was possible. The trajectory of the *specus* is again picked up in the area where the magnetic survey revealed the most western architectural traces. Here, a modern intervention revealed the presence *in situ* of this granite *specus* in connection with some of the schist plates used to cover the conduit. Interpretation of the magnetometer evidence, allows us to assume that from here the *specus* follows exactly the street trajectory of the *decumanus maximus* until it reaches the southern angle of the forum. Certain geophysical data, in particular those from the GPR survey, suggest that from this node under the street crossroads (maybe the location of a small distribution tower) the main aqueduct splits up in several conduits, with as main destination the forum square (in particular the water basins near the temple) and the adjoining forum baths. At this central town location the fresh water had descended some 30m from its source area.

III.3 THREE-DIMENSIONAL VISUALISATION OF EARLY IMPERIAL *AMMAIA*

M. Klein, G. Weinlinger, F. Vermeulen

Introduction

Ammaia served as an ideal test site to apply state-of-the-art technology for non destructive surveys uncovering the remains of a complete Roman urban settlement due to its exceptional condition of preservation. The resulting data, mostly in the shape of magnetometer and Ground Penetrating Radar images and their archaeological interpretations, are being used to approach a complete virtual reconstruction of the town and its surrounding landscape.

The visualisation of the geophysical results is approached by referencing the existing data of *Ammaia* with better preserved and excavated sites of the region comparing similar structures and dimensions, aiming to define local architectural features and details of decoration. Digital Elevation Models, geophysical results, 3D Laser and LiDAR (Light detection and ranging) scans are taken into account to build the ancient terrain, where the results of the architectural 3D reconstruction will reside. Special programs are used to achieve realistic results and breathe life into the scenes. Sophisticated hard- and software, such as an in-house available motion-capture system, is used to drive the animation of computer generated people to ensure correct movements while keeping the production costs feasible. Specialised render algorithms will enable the creation of terrain features, like plants, stones and boulders as well as populating the scenes with animated characters.

The methods involved in such virtual reconstructions are multifarious and have to be adapted to the special characteristics of this site. Procedures which had been developed and tested over the past years by the team of 7Reasons are applied and refined, while other new techniques had to be developed by this company, to suit the necessity of this specific project. The workflow as well as the different fields of activities involved in the ongoing process of the 3D reconstruction of *Ammaia*'s cityscape (Fig. 100) shall be described hereafter.

Workflow and fields of activity

Data acquisition

Typically, the data used during reconstruction projects is furnished by the scientific institutions involved in the project: documents, maps (old and new), graphics and images from archives, excavation reports, aerial photography, GPR, magnetic survey data, etc. and their interpretations by geophysicists and archaeologists. These data include also some new approaches to digitalisation including photogrammetric geometrisation. With the aid of current software and a series of images taken from several sides of an object, the creation of accurate geometry is possible without applying markers or circumstantial measurements. This procedure can be utilized in case of original artefacts of any size as well as of aerial vistas.

Archiving and data pre-processing

As part of the archiving activity a first processing of raw data from photogrammetric surveys (images) and scans (3D point clouds (Fig. 101) is achieved. To acquire high-quality 3D models for further steps in reconstruction projects, raw survey data is processed with different programs – the

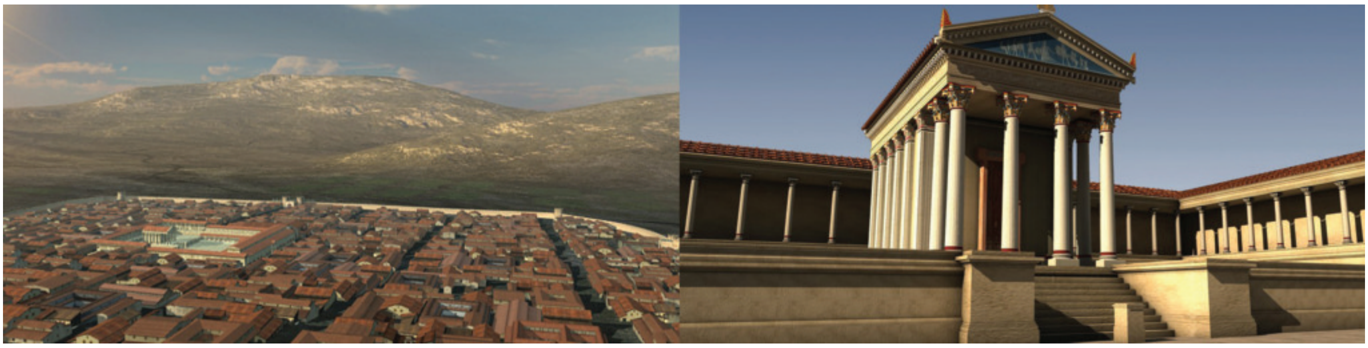


Fig. 100 Birds eye city view and the forum temple of *Ammaia* (early test images).

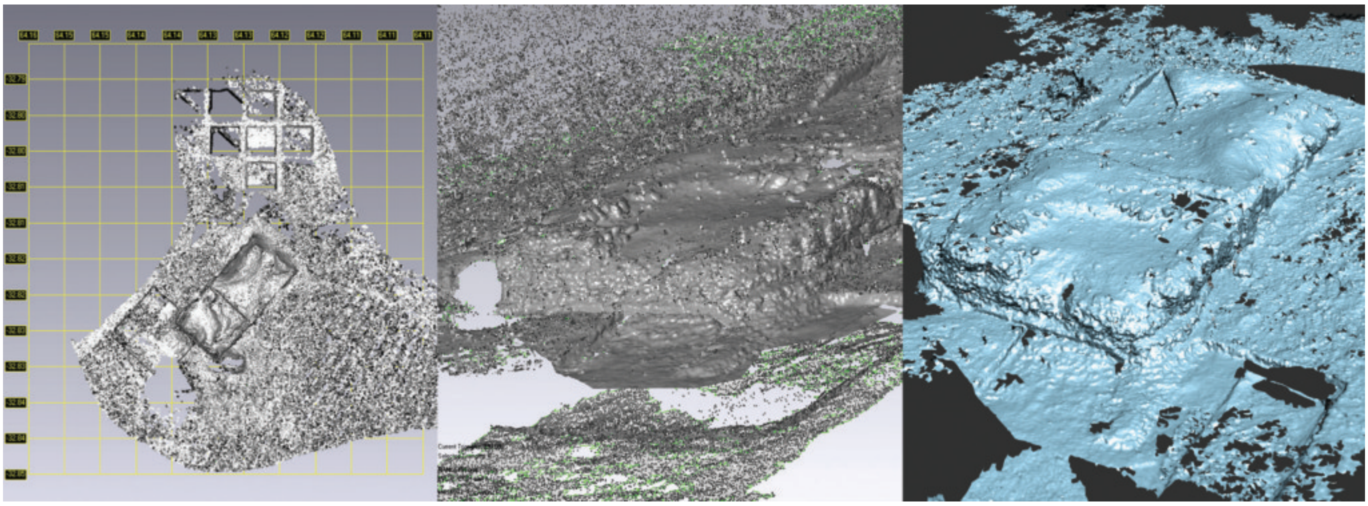


Fig. 101 3D Laser scan of the area of the forum temple podium (courtesy of The Discovery Programme).

extraction of textured models with different geometric resolution is usually one of the main issues to decide, depending on the environment, where the model is used or placed. One special procedure was established to suit the need of a large online database, where high-resolution scanned objects had to be reduced to 1% of their original density, while still preserving all of their visual qualities.

Archaeological databases

Due to the fact that several archives started to digitalize their archaeological finds, the need to present these data in an ordered and accessible way to a broader research community and the public is increasing. The scanned objects are in this way easily retrievable and can be displayed on the Internet. To present such media on various platforms, viewers like Adobe flash, 3d-PDF or Html 5 are used. Previews of these objects are presented in a lightweight format to make them accessible to all hardware devices. Accurate copies of the scanned data can be accessed by registration to the database and after a download used for ongoing research. By developing a special procedure we are now capable of processing great amounts of items within comparably short time (see also Humer *et al*. 2010).

This digital archiving activity was started in 2011 for the huge database of objects present in the archaeological labo and museum of *Ammaia*. Although meant as a research instrument, part of the scanned material, consisting essentially of well preserved objects such as *stelae*, architectural decoration, pottery, lamps, glassware, etc., can be of great use for the virtual town reconstruction.

GIS-based data integration

To combine data used in large-scale reconstruction like the re-modelling of urban settlements and their surroundings, GIS systems are used. Various georeferenced cartographic and topographic information is collected and assembled to construct a database which is essential in the particular task of reconstruction. Topographical data in the shape of a DEM (Digital Elevation Model), DTM (Digital Terrain Model) are needed for the generation of the virtual environment, which is thereafter further modified to achieve an approximate perception of the area during the desired period. To accomplish these tasks specialised terrain simulators and editors can be used to calculate the processes of erosion and the flow of water. The results are displayed in a fractal geometry, producing a highly realistic and natural appearance of the target area. A further task is the insertion of historical maps which can be used to approximate various historical landscape features like river courses, streets and settlement boundaries, including some of the archaeological and geomorphological field data merged via expert knowledge present in the multidisciplinary team. In this way a first base for a visualisation model of the terrain and landscape around *Ammaia* was achieved. This model needs to be further refined in the future once more data, such as from palaeoecological and additional geomorphological research, are available (Fig. 102, 103).

Process of Reconstruction

Cultural landscape, buildings and artefacts are digitally recreated or their scan incorporated into virtual environments to present them in their presumed original context. Through constant consultation and discussion with the team of archaeologists authenticity and correctness of the models is ensured. With the help of the excavation plans, the building remains and a selection of unearthed artefacts, the development of comprehensive models of ancient life in and around *Ammaia* is sought. The ancient town and the use of its surrounding environment by the Roman and Lusitanian inhab-

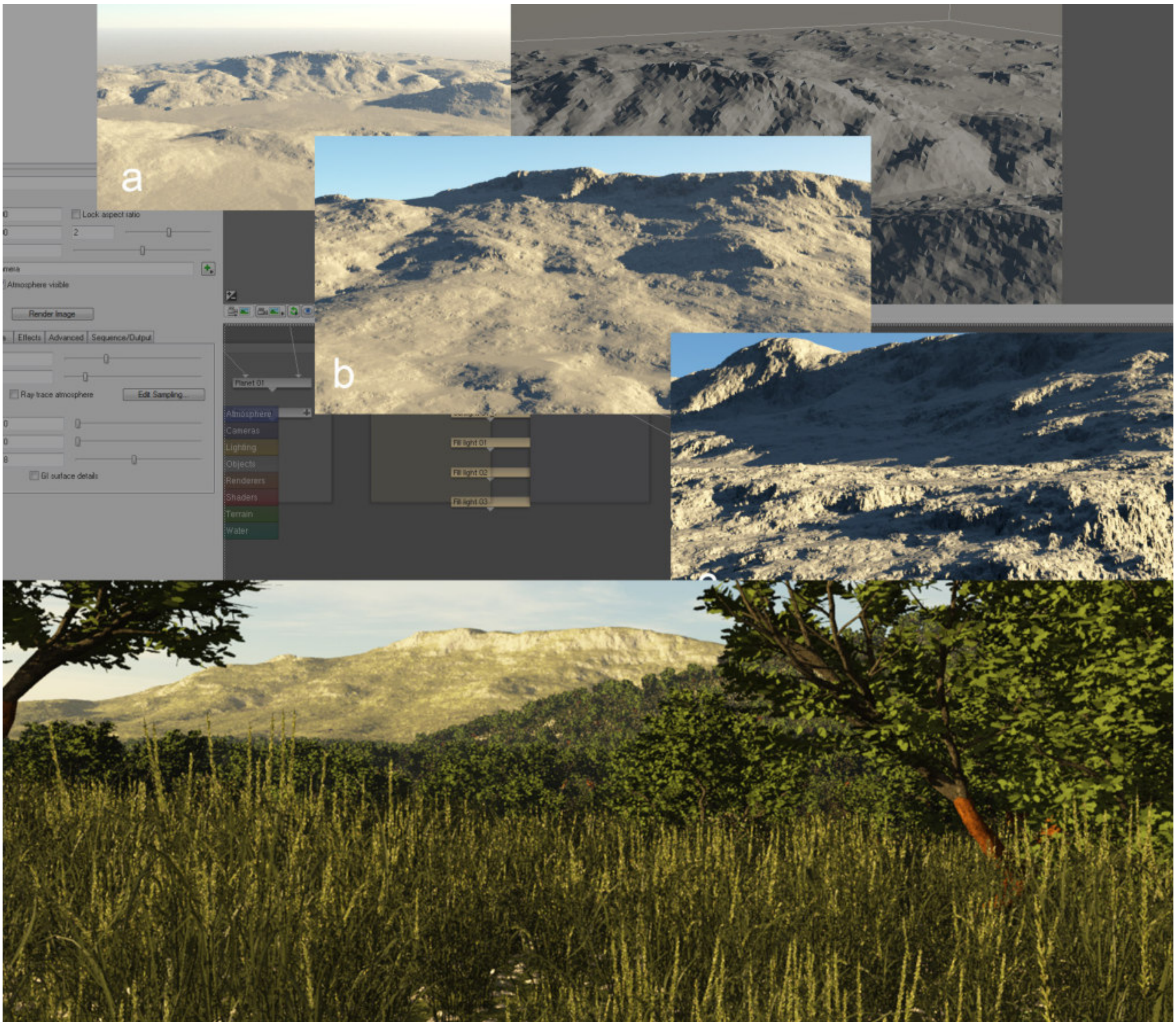


Fig. 102 Upper: Digital terrain and landscape model in various stages of the editing process. Lower: a virtual view on the landscape in Antiquity from the *Ammaia* site area towards the hill of present day Marvão.

itants, types for representative buildings as well as for vernacular architecture are recreated. To increase the detail of singular buildings and complexes where the archaeological data are more precise or certain, such as the forum, the baths, the southern gate and several well studied *insulae*, and to show functionality of interior spaces, finds of the site are displayed at their presumed position. Very often the finds of particular parts of the archaeological site are not sufficient enough to allow for a comprehensive reconstruction. In this case, data has to be obtained by comparative research, by using information from sites of the same period, geographical region and importance, in regular discussions with the archaeological consultants. For the site of *Ammaia*, the Lusitanian context and in particular data from well excavated parts of the provincial capital *Augusta Emerita* and the extensively studied site of *Conimbriga* are of particular relevance, as are in more general terms data pertaining to excavation sites from all over the Iberian Peninsula (see chapter III.1).

Methododological framework

By way of several sessions involving archaeologists, historians and other researchers, the outline of the project was determined: crucial are what scope the reconstruction should have, what kind of material is accessible and which form the final presentation will take. After viewing the existing material first approaches were then developed: for the settlement reconstructions a low resolution model was drawn with settlement boundaries, streets, the space occu-

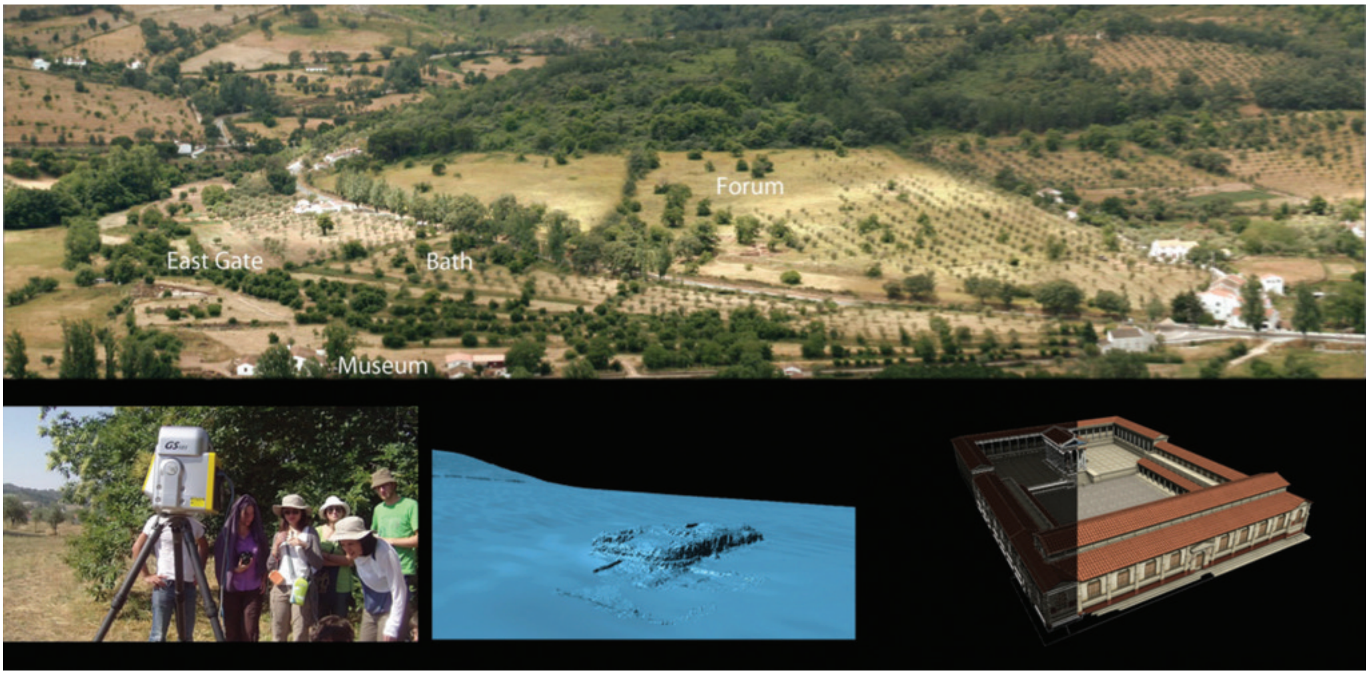


Fig. 103 Digitalisation of the forum temple area and a possible visualisation within the forum complex.

pied by buildings, etc . Hereafter, the public areas with representative buildings (which are typically better documented) were delineated and the rest of the settlement zones identified. Very helpful is the fact, that in the Roman period, and in particular in the Early Imperial phases which we chose to visualise first, most architecture, especially public buildings and certain categories of houses and shops where built in accordance to a comparatively uniform code of design, presenting a common tradition of (provincial) Roman culture and of the social class or people with Ibero-Roman background. To determine these building types the archaeologists supplied excavation results, images of still existing built examples and some historical descriptions and drawings. Also specially designated areas within the urban and suburban settlement, like gardens with outbuildings or defensive architecture have to be marked and drawn in 3D (Fig. 104, 105).

Once the crude 3D model of the settlement was designed, it was inserted into a realtime engine, to allow modification and interactive display during further discussion sessions with the archaeologists in charge. This point is crucial in every project, as several questions remain characteristically unsolved, which can now be studied in detail with the help of the model and by incorporating the fine data like interpreted and integrated geophysical maps, the new terrain model and excavation plans. When satisfactory answers have been found, and the layout thus modified, the houses in the scene are textured, to give them a realistic appearance and also the landscape, roads and other features are modelled more in detail. Sometimes the decision is made to show a close-up of certain objects, like a single house or compound. In this case a model with higher degree of geometric resolution has to be created, showing also the possible interior organisation, like rooms, stairs, and corridors. To complete the scene, correct building materials, interior and furniture have to be shown. This is a task which is of similar importance as the quality of the general layout, if the overall result should be scientifically acceptable as reconstructed model and also geometrically correct.

As the Radio-Past project also programmed the creation of reconstructions by way of a short film, a camera path is created to define the sceneries. According to the camera´s clipping, scenes can be further refined and a storyline can be established. To provide reference to human proportions and to suggest a more interesting backdrop, animated human figures and more artefacts characteristic for the given time period are inserted. This material can also be used to produce interactive 3D real-time applications, allowing the user to freely move around the scenes and access information on demand. This is particularly relevant here in *Ammaia* as the site has its own on-site museum.

Specific techniques used in the *Ammaia* project

Modeling and texturing of objects

To sketch out ideas for a reconstructed scene a coarse geometry was laid out to be presented to and discussed with the scientific partners. Various methods of production were

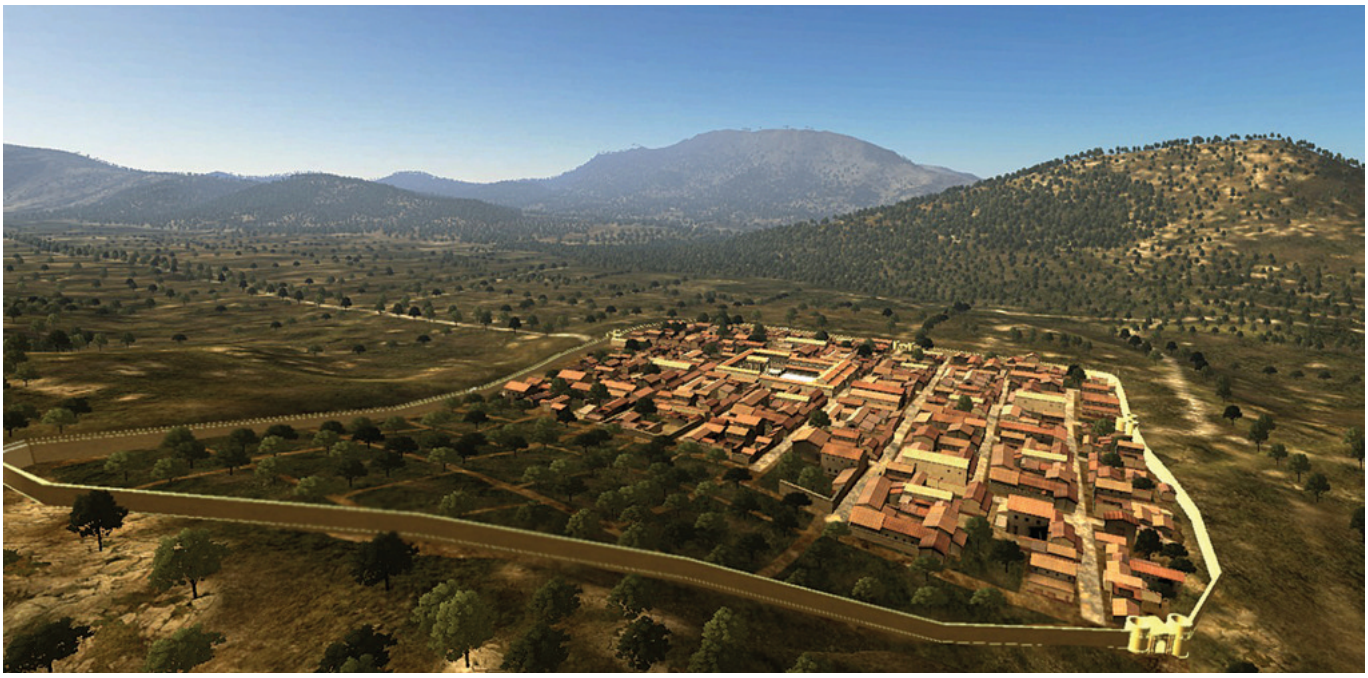


Fig. 104 Preliminary view of the reconstructed Early Imperial *Ammaia* within a 3D realtime environment (view from SW).

implemented depending on the use for the final format. Accuracy and authenticity is crucial to substain a high quality together with the documentation of the resulting objects. Although in *Ammaia* structural remains of walls are well preserved this is much less the case for building floors, road surfaces and wall or ceiling decorations; there was much spoliation in the course of the centuries and during scientific excavations only few pieces of stucco were actually found. This meant that for texturing many comparative data from other Iberian sites were needed. When then the desired level of detail is achieved, the process of texturing, or mapping images onto the surfaces, was applied. A wide range of software (e.g. Blender) is being used for the construction of different items and all of this demands highly skilled personnel to ensure a high quality output.

Landscape and cityscape visualisation

Incoming data from GIS applications were transformed according to the needs to achieve a historical accurate simulation based on manually driven construction methods. The best available technology to output a highly realistic terrain is a fractal approach. The detail of the geometry is adapted depending on the distance to the virtual camera. With this method replicas of millions of items (boulders, trees, houses, etc.) can be spread over the landscape. Certain terrain features like streets, urban boundaries, agricultural land-use or waterways can be defined by simple maps possessing RGB and gray scale values, which are called splat-maps. The ease of use of these splat-maps is one of their advantages, allowing to assemble the information as a simple image which can be edited by the non computer-graphic specialist members of the project team.

If available, LiDAR data can also be used to filter and discard various recent features like vegetation growth and modern construction, allowing in some cases the detection of archaeological remains. Apart from the archaeological interpretation of data from geophysics survey and excavation, aerial images taken from airplanes were used to build geometry without the cost-intensive and laborious procedure of a LiDAR scan with the use of photogrammetry. Fluid simulation was applied to visualise realistic water and simulate river flows of the river Sever and its tributaries (see also Humer *et al.* 2011).

Although planned for the near future, at the moment of writing no high resolution LiDAR coverage data were available for the *Ammaia*-site. This was however mainly resolved by the availability of a dense DGPS survey (see chapter II.2) which revealed not only the current microtopography in sufficient detail, but eventually helped in filtering out modern elements in the landscape, such as current vegetation and agricultural terracing. Together with the geomorphological survey data they provided a crucial base for the simulation of the early Imperial Roman topography of the area, easily including all elements of standing architecture visible above ground today, such as parts of the city defences and excavated building structures.

To date, however, many questions remain for a detailed visualisation of cultural and natural vegetations, as we lack palynological data, but expert knowledge about Roman agriculture and aspects of natural vegetation in the region are available and aerial photography evidence was very sugges-

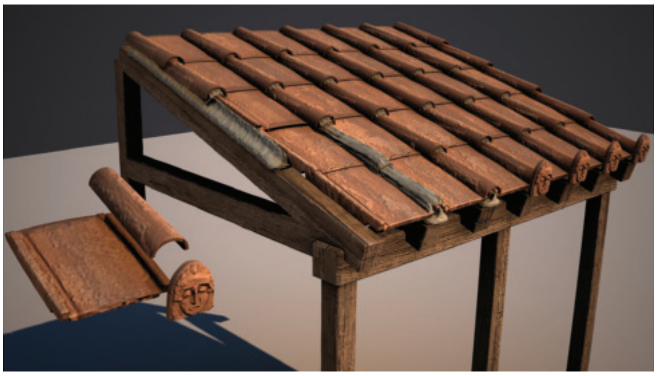


Fig. 105 Detailed visualisation of Roman roofing. Only for the decorated finials no hard archaeological evidence was found in *Ammaia*.

tive in locating regularly divided agricultural land in the Roman city perimeter (chapter II.3; Corsi and Vermeulen 2008).

Character creation and animation

Still in process, as part of the visualisation of Early Imperial *Ammaia*, is the insertion of characters and animations. Humanoid and non-humanoid 3D-models are being created with a toolset specialised for organic construction. Depending on the needs this process can start up from a skeletal phase building up volume by applying muscular systems and ending at the texturing process.

When the desired shape of a model is reached, a kinematic bone structure is inserted with a mesh-binding which allows animation of various parts to proceed. The results can be used for highly detailed visuals as well as crowd animations to enliven reconstructed sceneries, adapted here to the specifics of a Roman or Romanized town and suburban population with a strong link with the countryside and its exploitation.

Documentation of the reconstruction process

The decisions taken during the reconstruction process are documented and commented in online blogs (Fig. 106, 108), citing used material, comparative sources, etc. This ensures not only a good communication within the project team, but also transparency, traceability and a scholarly approach to the topics in question. With this proper base the evolution of reconstruction concepts can be published later on in specialized scientific papers. Without these measures most of the work conducted would be rendered meaningless, as the main goal cannot only be to produce attractive images of historic objects and scenery, but to gain new insights and knowledge, also about methodological and best practice issues.

Output

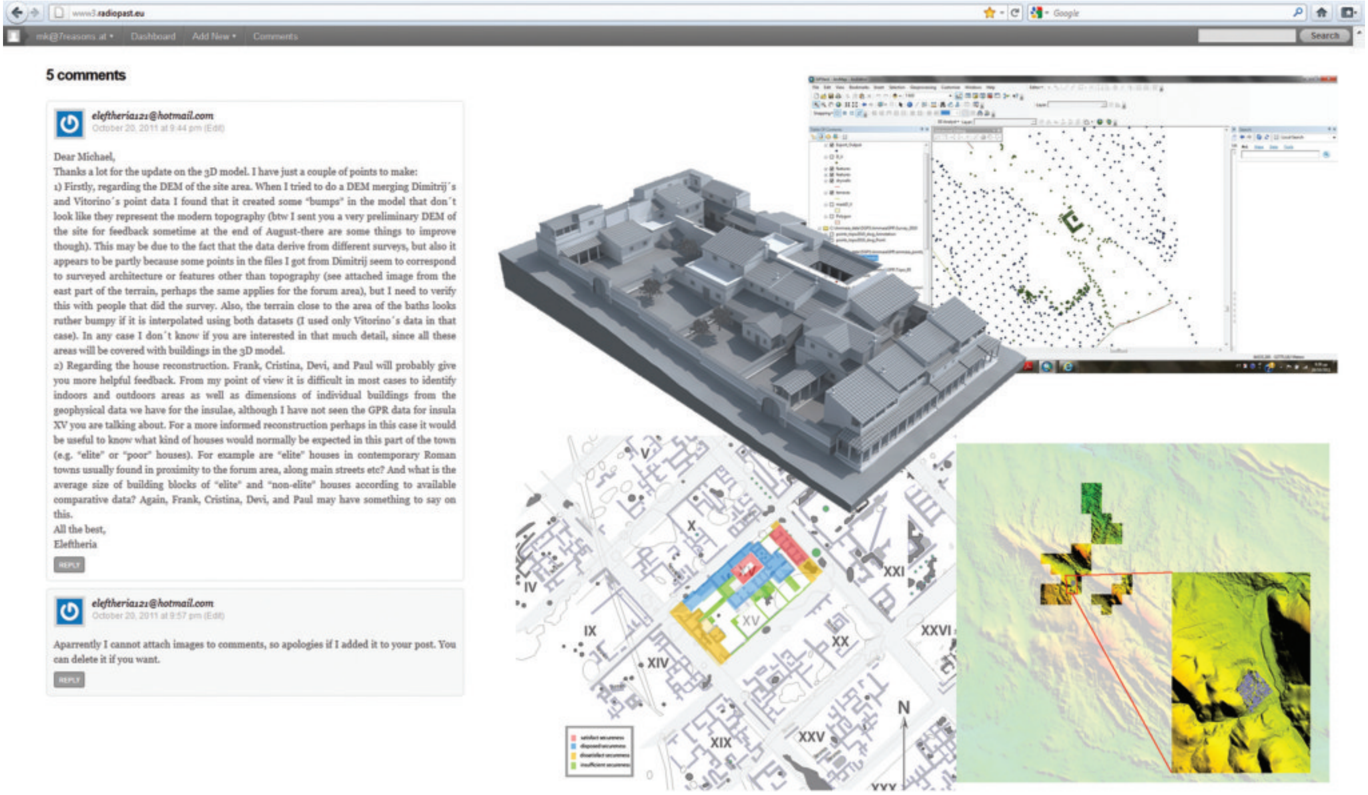
The Ammaia model

The work on reconstructing *Ammaia*, which started in 2009, is a long haul endeavour. At present a first model is accomplished. It consists in the first place in a series of tentative images and views on a Roman town in its heyday, sometime in the second century AD. It is still idealized and simplified but it forms the acceptable base for scientific discussion as well as for a first impression for the broader audience of a possible ancient reality (Fig. 107), helping them also to identify the known archaeology in its local, regional and wider cultural, topographical and historical context. It represents one collective team view on the newly detected features, merged with earlier data, of a lost Roman town in its changed landscape. There are also different degrees of detail. Areas where ample excavation evidence was available, such as the public zones of forum, south gate and bathhouse, can be provided with much more detail and higher degrees of certainty. Here the reconstructions are more reliable and detailed, with propositions for different versions of interpretation (see also: Corsi, Klein and Weinlinger 2012). This is to a certain extent also possible for some specific zones where the three main geophysical methods were applied with great success, such as is the case for a number of housing *insulae* west and south of the forum. Their fine integration provided another type of ground truthing and, therefore, also much more detail about plans, floors, functions, etc. Nevertheless, other areas of the cityscape will at the current state of research remain more tentative to reconstruct, and thus we chose to limit the detail of visualisation here.

Realtime applications and short film production

The model is not just a set of images, static, unchangeable and immovable. Realtime applications are being made for almost all platforms and hardware devices delivering interactive scenery to the spectator, inviting him to discover reconstructed sites and information. The long lasting experience of 7Reasons in these fields enables us to apply innovative solutions like archaeological sandbox-systems to aid communication between scientists and IT-artists. This principle can also be used to display ideas of a project team to a broader audience. The increasing quality of the current game engines allows us to produce in near future not only realtime but also film footage without the need of rendering.

The classical short film production will always be a major part of the media market due to its advantage of linear storytelling. To produce hundreds of thousands of images, which are assembled and edited in the post-production, we use a considerable number of computers combined with a



5 comments

eleftheria121@hotmail.com
October 20, 2011 at 9:44 pm (Edit)

Dear Michael,
Thanks a lot for the update on the 3D model. I have just a couple of points to make:
1) Firstly, regarding the DEM of the site area. When I tried to do a DEM merging Dimitrij´s and Vitorino´s point data I found that it created some "bumps" in the model that don´t look like they represent the modern topography (btw I sent you a very preliminary DEM of the site for feedback sometime at the end of August-there are some things to improve though). This may be due to the fact that the data derive from different surveys, but also it appears to be partly because some points in the files I got from Dimitrij seem to correspond to surveyed architecture or features other than topography (see attached image from the east part of the terrain, perhaps the same applies for the forum area), but I need to verify this with people that did the survey. Also, the terrain close to the area of the baths looks ruther bumpy if it is interpolated using both datasets (I used only Vitorino´s data in that case). In any case I don´t know if you are interested in that much detail, since all these areas will be covered with buildings in the 3D model.
2) Regarding the house reconstruction. Frank, Cristina, Devi, and Paul will probably give you more helpful feedback. From my point of view it is difficult in most cases to identify indoors and outdoors areas as well as dimensions of individual buildings from the geophysical data we have for the insulae, although I have not seen the GPR data for insula XV you are talking about. For a more informed reconstruction perhaps in this case it would be useful to know what kind of houses would normally be expected in this part of the town (e.g. "elite" or "poor" houses). For example are "elite" houses in contemporary Roman towns usually found in proximity to the forum area, along main streets etc? And what is the average size of building blocks of "elite" and "non-elite" houses according to available comparative data? Again, Frank, Cristina, Devi, and Paul may have something to say on this.
All the best,
Eleftheria

eleftheria121@hotmail.com
October 20, 2011 at 9:57 pm (Edit)

Aparrently I cannot attach images to comments, so apologies if I added it to your post. You can delete it if you want.

Fig. 106 Blog discussion of a suggested reconstruction of Block X of *Ammaia*.

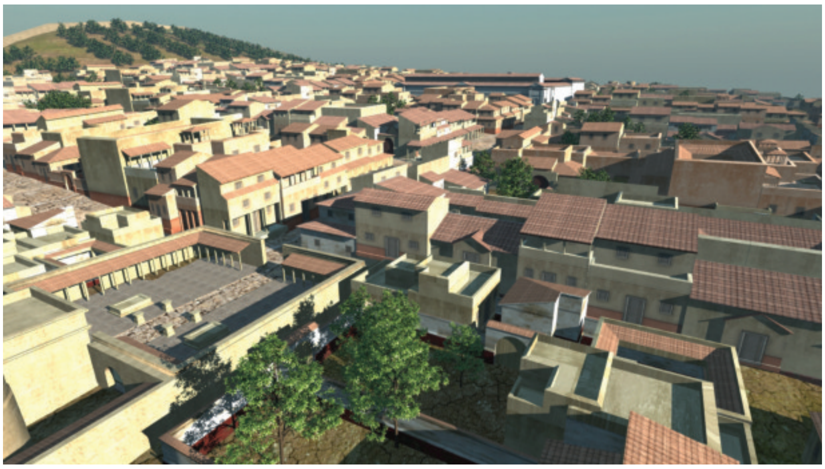


Fig. 107 Tentative view on reconstructed *Ammaia* from the south.

render-farm. The end product is used for wider audience educational and informative activities that bind an account of the actual field research by the archaeological team to the virtual archaeology reconstructions.

Consideration

The on-going reconstruction and visualisation work of the early Imperial phase of *Ammaia* is the result of interactive work and discussion among team specialists of different fields, using a wide array of local, regional and supra-regional data. When working with Roman towns, such as this one, we can normally rely upon a huge patrimony of available models for public and private buildings, and on the detailed knowledge we have of local traditions and building techniques. By means of the archaeological study of available building materials and artefacts we can infer many aspects of the existing architectures at a good degree of likelihood. Nevertheless, we are well aware that the reconstructions are tentative and experimental, and that new field data or the availability of new tools for data processing could in the future make adaptations necessary. But

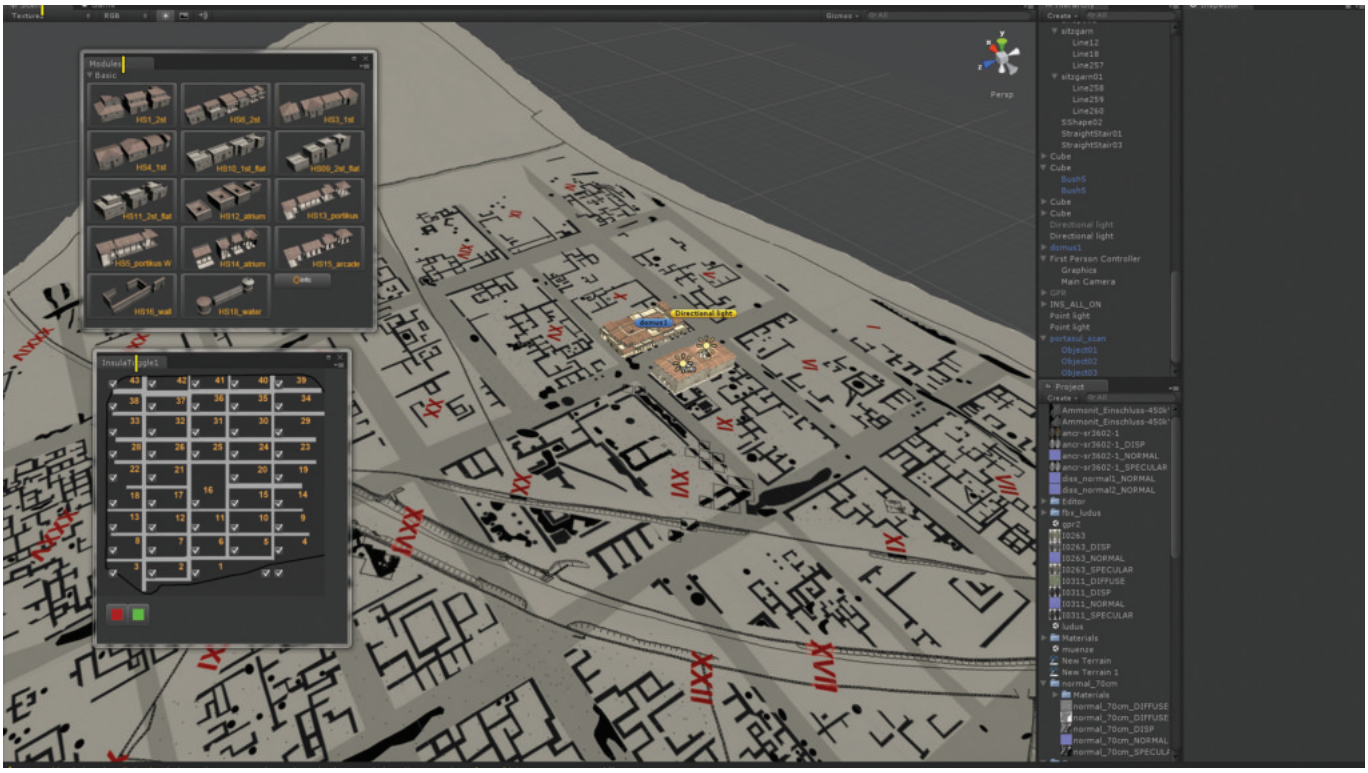


Fig. 12 Realtime editor with drag and drop library of building-block modules to be positioned on the geophysics interpretation layer of *Ammaia*.

this process of confrontation is very helpful in understanding the reconstructed spaces and architectures and in approaching a town from a more realistic 3D perception. Ethically, it is essential that in these reconstructions we clearly state which parts are integrated and which are existing, and this aspect is especially delicate when dealing with datasets taken from non-excavated evidence, even if it was shown above that the geophysics work very well at *Ammaia*.

But it must be stressed that, even if some of the reconstructions will have to be revised in the future, the attempts that are being made at *Ammaia* can surely contribute to the scientific debate on Roman urbanism and architecture in a provincial-Roman context such as *Lusitania*, as well as bring the results of large scale non-invasive surveys within the reach of a wider audience.

CONCLUSIONS: SURVEYING A TOWNSCAPE

C. Corsi, F. Vermeulen

At this stage of research, we can say that *Ammaia* has produced one of the best known urban layouts of Roman towns in the Iberian Peninsula. This statement takes into full consideration the difference between the delineation of the main topographical, planimetric and monumental aspects of the settlement and the understanding of its historical, social, chronological and monumental complexity (Johnson 2012). The advancement of knowledge about the town over the last four years is astonishing and although some recent publications still seem to ignore these new data (e.g. Pereira 2010; Oliveira 2010; Pereira 2010), what we now know of the urban pattern, the individual housing, the town's public spaces, etc. is at least remarkable.

Yet the integration with the data from excavations, which are at the moment undergoing full re-processing, and the nearly finalized analysis of many categories of finds, undoubtedly procured a deeper understanding of the main developments of the town, in spite of the lack of historical sources. Therefore, we can finally place *Ammaia* in its background of road connections, resources exploitation and economic and social history, obtaining in this way a much better idea of the landscape setting, character and chronological context of this town.

With Kaiser, we have to underline that while topography does not change much in the course of times, historical, political, social and economic factors play a key role in shaping the spatial organization of a town. This organisation interacts vividly with many other dynamics and conditionings, like local building traditions, availability of certain materials, technological shared know-how, meteorological elements, and so on (Kaiser 2011: 14). The "radiography" that we were able to recompose of the subsoil of *Ammaia* and its *suburbium* lacks of course the chronological depth, and only in few areas where stratigraphical excavations could provide some information about transformations and changes, we can draft a basic chronological scheme of evolution of the urban tissue and of some of its single buildings. Still, an accurate interpretation of the bi-dimensional data of the geomagnetic and earth resistance surveys, and mostly of the high resolution three-dimensional view of the subsurface structures detected with the GPR survey can support a tentative sketch of the town's developments.

The making of a Roman town

Possibly, the most intriguing part of the analysis of the data collected with the total survey of *Ammaia* has been the identification of the earlier phases and of the process of building up a new town from Augustan times onwards, with its evolution and the progressive "consumption" of its original plan through times. When linking the geophysical prospection results to what can be understood from stratigraphic contexts some interesting observations can be made about changes to the original concept.

The most reliable data come from the *insula* south of the forum (Block XXVI) which, in its western half, hosts the bath complex. Here excavations carried out in recent years have proven that the first buildings occupying the block were limited in extend, and that probably the limit of the *insula* was originally in line with the other adjoining *insulae* of the orthogonal system (XXV and XXVII). When the works for the construction of the baths started, a part of the southern limit of the *insula* was extended south-eastwards, invading the roadway by a couple of meters. This "expansion" of built areas to the detriment of the open public spaces is a very frequent phenomenon, which seems here already to happen in the course of the Flavian period.

What happens in the extreme eastern corner of the town (Block XXXVIII) is also indicative. According to the ideal scheme, this block should have been delimited by the *decumani* M-N and the *cardo* D (see Fig. 88), ending on the eastern side against the town walls, and its dimensions (including the bordering streets) should have been close to 79.87 by 44.37m (= 2¼ by 1¼ *actus*; see III.1.a). Instead, already in the late first or second century AD, buildings invaded fully the last stretch of the street which ends against the walls. To understand the underlying project, we can stress the presence of two perpendicular segments of "secondary streets" which reach the centre of the block: possibly, they originally delimited one housing unit or, better, a shop (Pereira 2010: 159). In the course of the several restructurings and transformations that affected the building, parts of these streets (a sort of *angiporti*) were incorporated in the buildings and progressively reduced to alleys. In the course of the fourth century, the last segment of the *decumanus* was completely overbuilt and incorporated into a housing unit, which has been interpreted as a "low-class" unit (Pereira

2009: 85). It is remarkable that in the same block, but on the opposite side of the side street perpendicular to the *decumanus* M, part of a *praefurnium* has been brought to light. The presence of a heating system suggests that the house in this part of the block was an "upper class" one, in this way giving the impression that there was no social distinction in this sector between different levels of dwellings.

The same consideration applies to the erection of public monuments and infrastructures. Chronological data from the forum complex of *Ammaia* are not yet very detailed, but we can distinguish at least two important phases of construction, following each other in a period of less than fifty years. This long time span for the full development of the public centre is surely not exceptional, as it has been proven in other towns like *Italica* that the programme of monumentalizing the town is estimated to have started in the Augustan period and was not completed until the reign of Tiberius (Rodríguez Hidalgo and Keay 1995: 402). Still, considering the difficulties that the Roman architects had to overcome to level quotes differences on the site of the central square and how challenging it was to build the platform that would have to host the monuments and buildings of the forum, quite some financial, technical and manpower resources must have been available over a longer period of time.

Confronted with the data collected in many places in *Hispania* about the consistent initiative taken by Claudius in the monumentalisation of forum complexes (Persichini 2012: 460-461), the opinion of Tsirkin (1994: 230) that "Claudius did very little" in the Hispanic provinces can be firmly contested. At present it seems that also in *Ammaia* the reign of this emperor produced a flourishing development and it might well be that the forum was by then finalised in its first phase. At the same time we possibly collected some monumental evidence in the forum-temple area proving the benevolence of Vespasian, even if we lack a clear correlation with the political-administrative aspects of the reform of the town's juridical status (see: I.1, I.3).

While the forum surely took several decades to be fully finalised, the street system and a decent system to evacuate surface water at heavy rainfall, had to function quite soon. This is particularly crucial when taking into account of the position of the town on a slope. One element to stress in this respect is that one of the oldest infrastructures to be constructed in the central area of *Ammaia* is the sewer under *cardo* D, which flows into a drain outside the walls. In this case, we have the proof that the original plan implied the construction of the street, even if it has not been understood if the street was ever paved before being fully invaded by buildings. The fact that the drainage system was the first element to be built has been assessed in other sectors of the excavated areas, as has been proposed and well documented for other towns, such as *Augusta Emerita* (Hernández Ramírez 1998: 88).

The analysis of the layout of *Ammaia* contributes hugely to the understanding of Roman urbanism in this provincial context. Few Roman towns are known with such detail and most of all in such completeness.

Here the analysis of the ideal scheme of an orthogonal town, laid out with immaterial lines, has proven that the dimensions of the *insulae* were not always homogenous, and that instead at least the two central rows of blocks, included between *decumanus* G and the *decumanus* I (see Fig. 88), were wider. This is understandable when we think that since the original planning the two central blocks were expected to incorporate the forum.

The ratio of the blocks as established in *Ammaia* does, however, not find a perfect comparison in the Hispanic provinces. But this is just another proof of how town-planning canons were adapted to the local conditions and how much the reality of a town with its three-dimensional buildings differs from the immaterial ideal planning schemes.

Still, we cannot help from including *Ammaia* into the general framework of the strategies adopted by the raising imperial power to control the wide territories that fell under domination of Rome, in the time span between the end of the first century BC and the beginning of the first century AD. Our belief that *Ammaia* was founded in the late Augustan age, based on the dating of the finds, is confirmed by the fact that *Ammaia* is fully embedded in the Augustan project of homogenization which seems to have inspired the planners of the first *Princeps* in the western provinces.

Even if now, that we can visualize these towns in 3D and therefore assess better their topographical peculiarities, the feeling that they all resembled each other resized, it is undoubtedly true that the regular gridded plans of most of these settlements built *ex nihilo* were inspired by the standards of uniformity well expressed in the *Res Gestae*, resulting in a process of urbanization without precedent when evaluated within its extraordinary geographical extension (Gros 1994: 47; Mierse 1999: 54-55*)*.

As anticipated, thanks to this research we must exclude now that "in overall terms, the layout of the *nova urbs* of *Italica* as a whole is without parallel in the Iberian Peninsula" (Rodríguez Hidalgo and Keay 1995: 406), but *Ammaia* cannot surely compete with the "scale and the architectural sophistication of individual houses" of the Hadrianic sectors of this southern Hispanic town.

Social landscape and urban dynamics

At the moment the analysis of the social landscape of the town of *Ammaia* does not result in very conclusive observations. We can underline that the survey has procured important insights in a certain "zoning", but this is mainly restricted to the broad distinction between residential and "industrial", translated to the topographical level this means, between sectors lying *intra muros* and extra-mural sectors.

When we come to the analysis of how elite and non-elite came to compete in *Ammaia* on the use of urban surface (Kaiser 2011: 18) we observe that the space "occupied" by the middle-classes seems to be the widest, at least in the early phases of the town. The evidence points to a restricted number of very large *domus*, and even the largest, an early (?) house built next to the forum and the later baths, does not take in enormous space. Instead most larger houses seem at the onset to be mid-sized smaller *domus*, while also many houses in the row look like poor and compact adaptations of this Mediterranean model. We do, however, observe a trend towards changes in properties through time which, at least in some cases suggest a move of these middle-class citizens upwards the social ladder. This seems indicated by several transformations of smaller *domus* into larger properties, even if it is wise to wait for excavation evidence confirming this.

To understand certain urban evolutions, considered normal throughout the first two centuries of the *Pax Romana*, we still miss part of the picture. As long as the presence of a theatre or amphitheatre is not proven, nor other large public amenities found, such as specific sanctuaries, large fountains etc., preferably highlighted by honorific inscriptions, we have no major insight into social behaviour here. In this sense, *Ammaia*, in spite of the striking regular layout that connotes it as a "Roman" town of the new Era, at the present state of research, lacks evidence for the adoption of one particular aspect of the imperial ideology: patronage and social competition. The absence of documented promotions of construction of public monuments suggests, at present, that these phenomena were not an active motor of urban life here. Also the epigraphic record, as shown by Mantas (see I.3), does not seem to support the idea that the wealthier classes of *Ammaienses* citizens were looking for consensus or imperial benevolence, or an enhancement of their social positions, undertaking acts of euergetism. Likewise, the finds from *Ammaia* do not argue for a widespread deployment of imperial symbols. Yet, we register a significant number of inscriptions devoted to *Iuppiter Optimus Maximus*, normally to be considered an indication that the imperial cult was almost certainly practiced in the forum complex (see I.3; Carneiro 2010: 84-85). This, together with the impressive size and architecture of the forum, seems to indicate that the town, at least in the first century of its existence, received full support for its development as a regional centre.

Considering the dominance of private over public buildings, the poorness of documented imperial symbols, the heavy thinning of quality and quantity of finds from the mid-second century AD onwards, we get the impression that the town was primarily established as a centre for the exploitation of the natural resources (mainly minerals and stone) of the territory, and that a certain decline during the later second, third and fourth centuries was more due to economical than political reasons. This general evolution of slowing down after the still flourishing Flavian period is somewhat different from what we see in many other Hispanic centres (Mackie 1990; Keay 1995; *infra*). Referring to the interesting approach by Simon Keay, who focused on highlighting the role played by ideology in the making of Roman towns in Iberia, we cannot but stress how the mechanism for the propagation of ideological symbols, namely the imperial cult, is so faintly discernible in *Ammaia*. None of the surviving evidence here proves strong 'imperial' connotations, nor explicitly advertises personal links with the emperor and his family (Keay 1995: 306). Even the use of marble features rarely, knowing that *Ammaia*, could easily have played a role in controlling the newly opened marble in the very nearby region of Extremoz (Cisneros Cunchillos 1988).

The later developments of *Ammaia* remain still difficult to grasp. During the later second and third centuries troubled times presented themselves for the Hispanic provinces. Due to an amalgam of social, economic and external factors (like marauding bands from North Africa and later from the East), most of the cities in the Iberian Peninsula declined in population and prosperity (Tsirkin 1987: 255-258; Mierse 1999: 298). On the basis of the survey data, integrated with the results of the recent ground-truthing excavations, we could conclude that the "precocious" appearance of the phenomenon of re-use of building materials, even in "public" monuments like the baths, discloses possible scenarios regarding the impoverishment of urban classes, phenomena which were already on-going in the course of the second century AD. The impossibility to date the abandonment of the quarry of limestone just outside the north-western gate, and of the important granite quarry of Pitaranha (see I.4), prevents us to speculate on connections between these locally attested events and transformations within the urban space. At the same time, we still do not know enough about the territory of the town to determine whether the rise of "magnificent country villas" can be interpreted as a sign of "discontinuation of new construction in town" (Tsirkin 1987: 256). What is, however, clear from piecing together the most significant chronological data obtained in the different excavation areas within *Ammaia*, is that during the later fourth century the town started a long process of depopulation and ruralisation, terminating with full abandonment somewhere during the early Middle Ages.

This urban decline from the fourth century onwards seems also visible in the geophysics data. When looking at indications for the "Christianization" of the city, we have to admit that at this stage no any indication can be signalled. None of the buildings seen through the "radiography" of the subsoil can be interpreted as a possible Christian "basilica", considering that, thanks to the presence of larger building features with an apse, this type of structure can normally be easily recognized. While the find of a Christian inscription in the area of Monte Velho remains uncertain (Oliveira 2010: 172-173), it is indeed possible that in this area, as documented elsewhere, rural settlements in the countryside were preferred for the construction of Christian worshipping places (Barral i Altet 1982 and 1992). In any case, we cannot but stress how the townscape of the later phases of *Ammaia* must have been different from the one that we propose in the reconstructions: the urban centre surely lost its characteristic uniformity and started to present "contrasts and anomalies", in both the horizontal as well as the vertical dimension. Probably each portion of the town had for a long time a different history, and the townscape became very heterogeneous and individualized.

We know from the archaeological record in the Iberian Peninsula that the crisis does not strike everywhere with the same intensity. Still, already during the third century several new wall circuits of Hispanic and Lusitanian towns, like those of *Barcino* and *Caesaraugusta*, testify to the shrinking of the city back to the old Augustan boundaries, while the walls around *Conimbriga* that cut through houses are grim reminders of the unstable situation during this period (De Man 2011).

For the later phases, the image of the "catastrophic" situation of the Iberian Peninsula from Late Antiquity onwards, built on the basis of contemporary sources, was significantly resized, almost questioning the dismantling role played by the barbaric invasions on the pre-existent Roman settlement patterns (Arce 1995; Arce 2002: 181-191; Alba Calzado 2004b: 209). Instead, the current trend is to point at a strong tendency to continuity in many Hispanic towns during Visigothic and medieval ages (Arce 1993; Olmo 1998).

These data have been most accurately documented in the Lusitanian capital *Augusta Emerita* whose nearby position and influence is of great importance for the *Ammaia* region. Mérida is one of those towns that survived the critical fifth century as an urban centre, but the opinions on Visigothic Mérida are highly discordant. What is clear is that both the Provincial and Colonial fora were abandoned and spoliated (Palma 2003: 432; Alba Calzado 2004b: 214), as were in the course of the fifth century also the porticoes, the temples and many other public buildings. The remaining structures are, however, often re-used to build private houses during the Visigothic phase (Alba Calzado 2004b: 215-216) and it remains undeniable that Mérida offers the most impressive sculpture of the Visigothic era in the peninsula (Alba Calzado 2004b: 209-211). The phase of Late Antiquity can even be defined as one of "urban saturation", as it seems that fifth century Mérida was more densely populated *intra-muros* as it ever was in the earlier stages. This is suggested by the fact that many public monuments were transformed into private houses, that public open spaces were "invaded" by dwellings and that an enlargement of the wall circuit was needed (Alba Calzado 2004b: 233). All this suggests completely different dynamics than those we can observe in the smaller urban centre of *Ammaia*, whose decline was irrevocable and its eventual transformation in an unsuccessful lost town, definitive.

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